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13. ABSTRACT (Maximum 200 words)

Cost estimates for USMC SINCGARS usage of BB-5590/U Lithium Sulfur Dioxide (LiSO2) Batteries, BA-590/U Sealed Lead-Acid Batteries, and BB-490/U Nickel-Cadmium (Ni-Cad) Batteries. Estimates encompass battery costs, charger costs as applicable, and disposal costs. Annual battery-related costs were estimated for USMC usage of mix of LiSO2 and Ni-Cad batteries ranging from 100% use of LiSO2 batteries to 100% use of Ni-Cad batteries; and for mix of LiSO2 and Lead-Acid batteries over the same range. Estimated hourly battery-related costs are $2.66 per hour for LiSO2 batteries, $0.34 for Ni-Cad batteries, and $0.30 for Lead-Acid batteries. Disposal related regulations and related documents are discussed and included in Appendices.

14. SUBJECT TERMS	Lithium Sulfur Dioxide Battery; Sealed Lead-Acid Battery; Nickel-Cadmium Battery; Cost Savings; Disposal Cost; Cost-Benefit Analysis
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MCR SERVICES GROUP, INC.

TR-9214-1

UNITED STATES MARINE CORPS (USMC) SINGLE CHANNEL GROUND AND AIRBORNE RADIO SYSTEM (SINCGARS) RECHARGEABLE BATTERY TRADE-OFF ANALYSIS

Prepared By:
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September 18, 1992

Prepared For:

MARINE CORPS SYSTEMS COMMAND (MARCORSYSCOM)
SINCGARS PROJECT OFFICE
QUANTICO, VIRGINIA 22134

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EXECUTIVE SUMMARY

This technical report was produced by MCR Services Group, Inc. (MCR SGI). MCR SGI is providing support to the United States Marine Corps (USMC) Single Channel Ground and Airborne Radio System (SINCGARS) project office. MCR SGI has produced three reports to date: TR-9150-1, SINCGARS Life Cycle Cost Estimate, dated 18 July 1991; TR-9150-1 SINCGARS Life Cycle Cost Estimate Addendum 1, which reflects updated USMC SINCGARS requirements; and SINCGARS Summary Version Life Cycle Cost Model (SVLCCM) Comparative Analyses, dated 25 November 1991.

In the Operations and Support (O&S) estimate presented in the Addendum, approximately 56% ($185 million) of the total O&S cost ($329 million) is associated with the procurement of the disposable batteries required for manpack and "vehicular dismountable" radios. Due to the magnitude of this expense, the USMC Project Officer tasked MCR SGI to identify and analyze the potential cost savings that could accrue to the USMC by utilizing rechargeable battery technology. The principal finding of this study is that the USMC could significantly reduce the O&S and disposal costs for USMC SINCGARS by utilizing rechargeable batteries.

Exhibit ES-1 shows approximate battery life of four alternative battery chemistries in the AN/PRC-119 manpack SINCGARS radio over a range of temperatures. Exhibit ES-2 shows the estimated annual primary battery-related costs in both the O&S and disposal phases for each of the three battery chemistries analyzed in detail assuming that the USMC relied exclusively on just one battery chemistry rather than a rechargeable/non-rechargeable mix. Exhibit ES-3 identifies the total annual primary battery cost for a mix of non-rechargeable Lithium-Sulfur Dioxide ($LiSO_2$) batteries and rechargeable Nickel-Cadmium (Ni-Cad) batteries. Exhibit ES-4

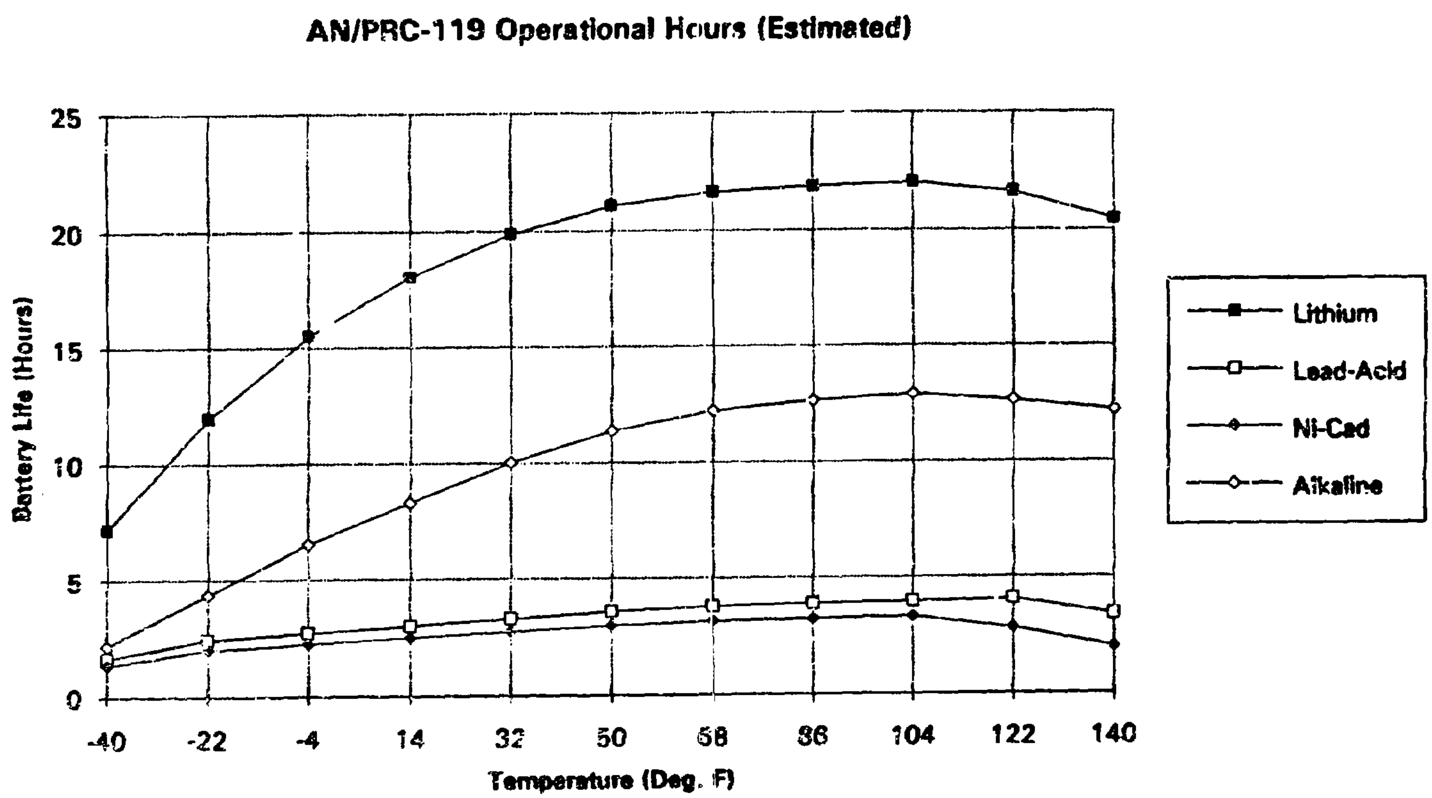


Exhibit ES-1. AN/PRC-119 OPERATIONAL HOURS (ESTIMATED)

Annual USMC SINCGARS Cost	BA-5590 LiSO2	BB-590 Ni-Cad	BB-490 Lead-Acid
Operations	$9,515,301	$1,514,053	$1,367,009
- Primary Batteries	$9,515,301	$898,491	$1,231,334
- Chargers	$0	$615,563	$135,675
Disposal	$2,881,710	$55,891	$11,944
- Transportation	$27,120	$2,260	$452
- Treatment	$2,854,590	$53,631	$11,492
TOTAL	$12,397,011	$1,569,945	$1,378,954
Operational Hours	4,651,925	4,651,925	4,651,925
Cost Per Hour	$2.66	$0.34	$0.30

Exhibit ES-2. SUMMARY OF DETAILED COST ESTIMATE

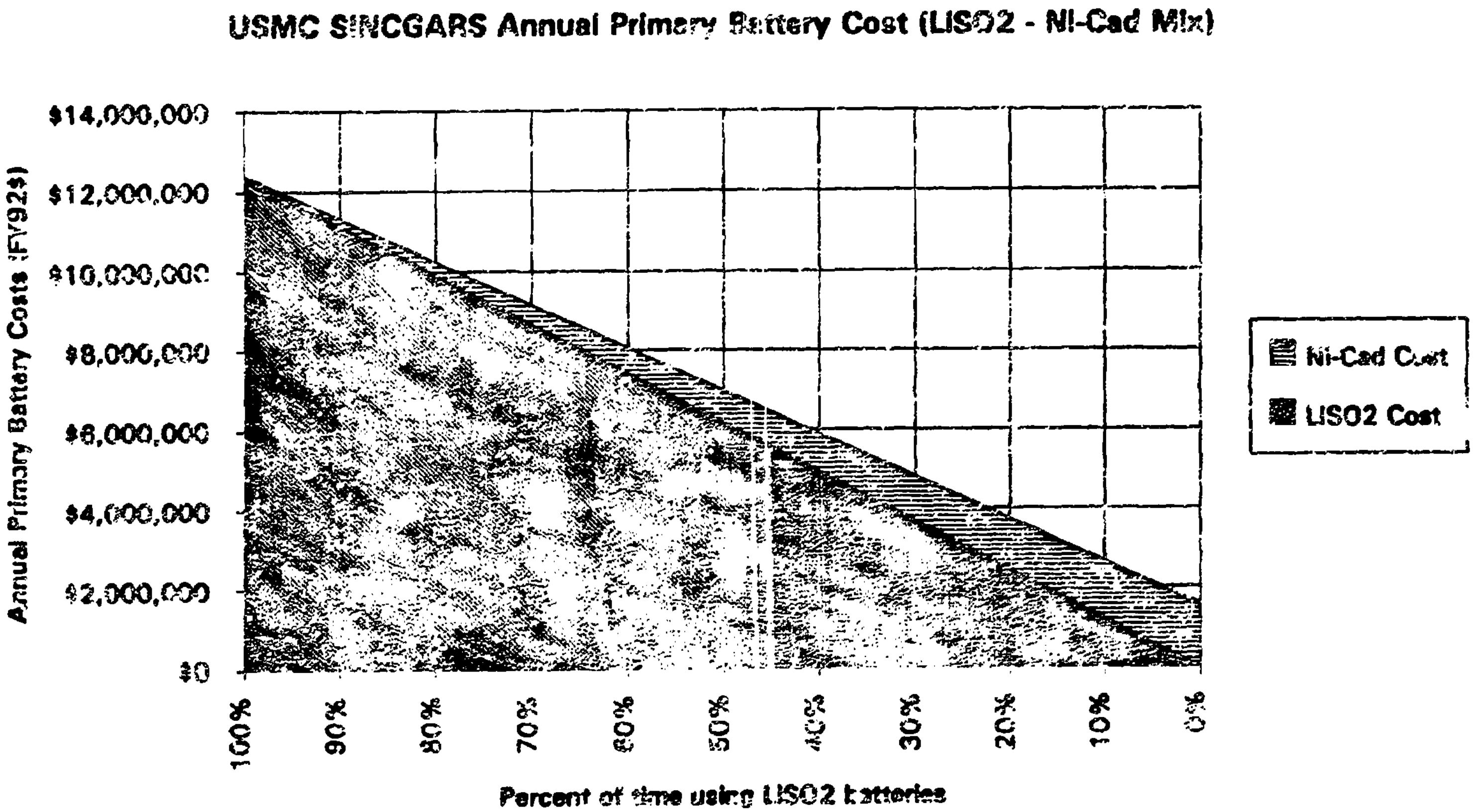


Exhibit ES-3. USMC SINCGARS ANNUAL PRIMARY BATTERY COST (LISO2-NICAD MIX)

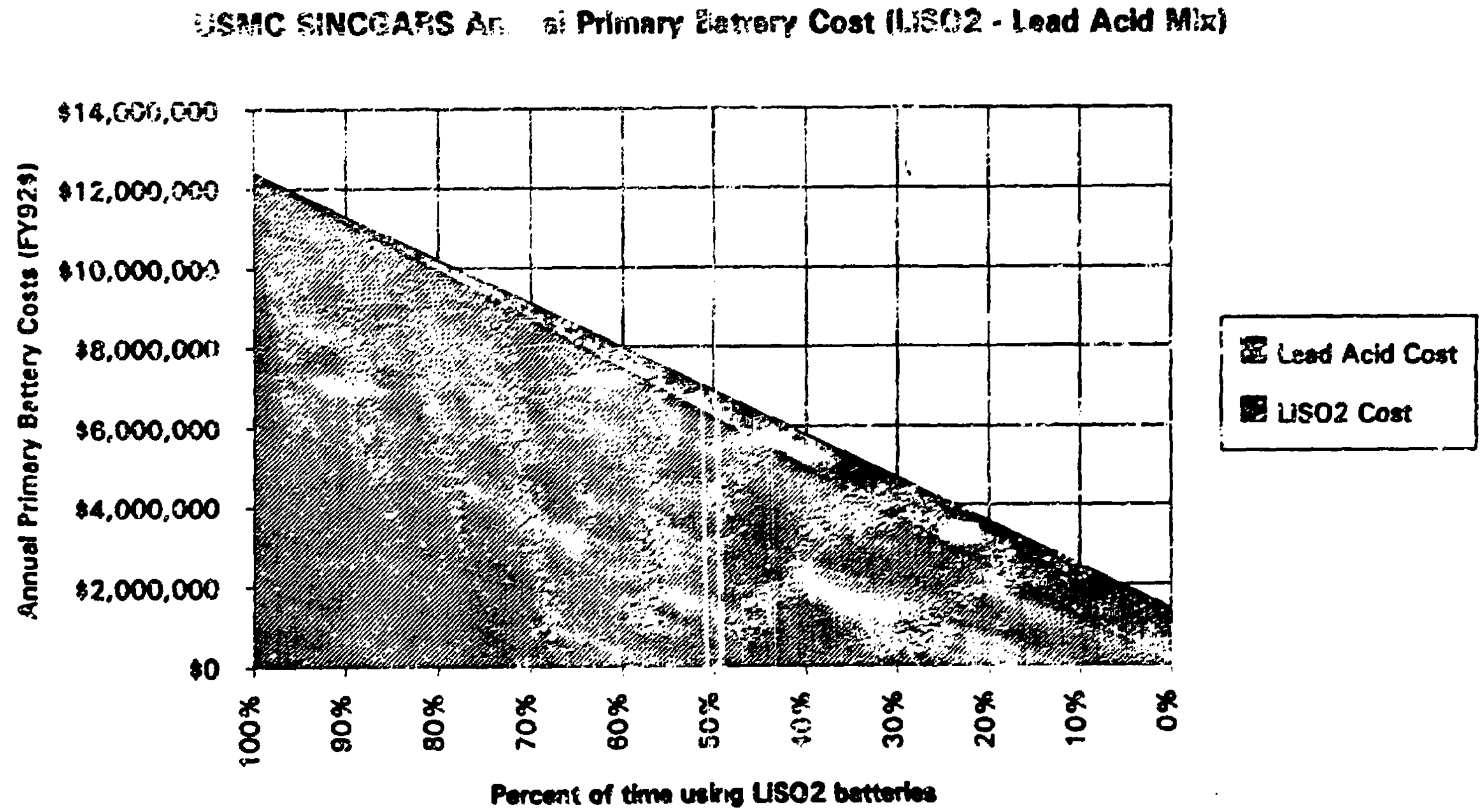


Exhibit ES-4. USMC SINCGARS ANNUAL PRIMARY BATTERY COST (LISO2 - LEAD ACID MIX)

identifies the total annual primary battery cost for a mix of non-rechargeable LiSO2 batteries and rechargeable lead-acid batteries.

Of the alternative chemistries analyzed, this study concludes that lead-acid batteries are the most suitable rechargeable battery chemistry available today for USMC SINCGARS. Lead-acid batteries exhibit the following advantages over the leading competitive rechargeable chemistry, Ni-Cad:

- lead-acid batteries are less expensive then Ni-Cad batteries on a life cycle cost basis.
- lead-acid batteries are simpler and more rugged than Ni-Cad batteries.
- lead-acid batteries exhibit slightly better discharge characteristics than Ni-Cad batteries.
- The constant-voltage rechargers used for lead-acid batteries are less expensive and ofer broader design choices than the constant-current rechargers required by Ni-Cad batteries.
- lead-acid batteries are easier to recycle.
- A range of lead-acid battery recyclers is available whereas there is only one EPA-licensed U.S. Ni-Cad battery recycler.

Although the purchase cost of a single lithium battery ($45) is lower than the purchase cost of a set of two lead-acid batteries plus a charger (approximately $500), one pair of lead acid batteries can replace approximately 52 lithium batteries. Those 52 lithium batteries would cost approximately $2,340, or almost six times as much.

A major difference between lead-acid and lithium batteries is with regard to disposal costs. Although all three battery types (LiSO2, Ni-Cad, and lead-acid) are classified by the Environmental Protection Agency (EPA) as hazardous waste, the disposal of lithium batteries is an especially complex and expensive process. Lead-acid batteries are readily recycled, and in most cases generators of lead acid batteries are paid a small fee by

recyclers. Depleted lithium batteries, on the other hand, cost about $9 each for disposal. This difference is magnified by the fact that one set of lead acid batteries can replace approximately 52 lithium batteries, for a total disposal cost savings of approximately $500 for each lead-acid battery set.

An additional consideration is that although one lead-acid battery weighs more than one LiSO2 battery, if an AN/PRC-119 radio will be operated in excess of approximately 110 hours without resupply, the total weight of the lithium batteries is in excess of the total weight of lead-acid batteries (including recharger). Therefore, there is a net weight savings if the radio will be used for more than approximately 110 hours without resupply.

I. INTRODUCTION

This introduction provides an overview of the United States Marine Corps (USMC) Single Channel Ground and Airborne Radio System (SINCGARS) battery trade-off analysis. The purpose of this section is to provide the:

- background of SINCGARS,
- purpose and scope of this trade-off study,
- organization of the report.

A. BACKGROUND

In 1975, the Army initiated development of a new combat net radio which could operate in an Electronics Warfare (EW) environment through the use of Slow Frequency Hopping (SFH). The new radio was required because the AN/PRC-77 manpack and AN/VRC-12 vehicular Very High Frequency (VHF) radios in use at the time were deficient in several areas including weight, size, reliability, quantity of channels, and communications security. These deficiencies became increasingly significant as Army tactical communications requirements dictated the need for more reliable and sophisticated equipment. The USMC, which was also using the AN/PRC-77 and AN/VRC-12 radios, decided to utilize the new Army radios for similar reasons.

Early in 1991, the USMC tasked MCR SGI to develop a Life Cycle Cost (LCC) estimate for the USMC SINCGARS requirements. MCR SGI's resulting SINCGARS Life Cycle Cost Estimate, TR-9150-1, was delivered on 18 July 1991. Refined USMC SINCGARS requirements were developed shortly thereafter. Therefore, MCR SGI developed an updated LCC estimate reflecting those new requirements (TR-9150-1, SINCGARS Life Cycle Cost Estimate, Addendum 1). Both documents provided complete LCC estimates for each of the two potential vendors: ITT and General Dynamics.

Exhibit I-1 provides a summary of the USMC SINCGARS general fielding procurement quantities used in the Addendum. Exhibit I-2 provides a summary of the ITT Operations & Support (O&S) estimate in BY91$ from the Addendum.

B. PURPOSE AND SCOPE OF THIS TRADE-OFF STUDY

In the O&S estimate presented in the Addendum, approximately 56% ($185 million) of the total O&S cost ($329 million) is associated with the procurement of the disposable batteries required for manpack and vehicular dismountable radios. Due to the magnitude of this expense, the USMC Project Officer tasked MCR SGI to identify and analyze the potential cost savings that could accrue to the USMC by utilizing rechargeable battery technology.

The scope of this study also encompasses the disposal phase in anticipation of the formal adoption of Department of Defense Directive (DODD) 500.4. Section B.2.C.(5) of the May 31, 1991 draft released by the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG) states that "the costs of demilitirization, detoxification, or long term waste storage should be included in the estimate when the program will require these functions".

C. ORGANIZATION OF THE REPORT.

This report consists of six sections and four appendices. This section has provided an introduction to this effort. Section II identifies and briefly discusses the technical characteristics of the three battery chemistries analyzed. Section III documents the ground

(Quantities)		FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	TOTAL
Config. 1	PRC-119A	1,250	1,500	2,000	1,710	1,845	1,745	10,050
Config. 2	VRC-88A	400	550	600	597	800	1,200	4,147
Config. 3	VRC-89A	300	275	300	285	330	325	1,815
Config. 4	VRC-90A	50	50	50	75	60	65	350
Config. 5	VRC-91A	400	550	600	500	400	410	2,860
Config. 6	VRC-92A	550	550	625	500	500	545	3,270
C-11561	SRCU	400	400	400	200	300	300	2,100
OE-254	Mast Ant.	500	500	640	730	700	560	3,630
	Inst. Kit	4,812	1,975	2,175	1,957	2,090	549	13,558
Total	Configs.	2,950	3,475	4,175	3,667	3,935	4,290	22,492

Note: Installation Kit quantities include kits for early fielding radios (Bancroft Buy)

Exhibit I-1. USMC SINCGARS GENERAL FIELDING PROCUREMENT

WBS NO.	WBS DESCRIPTION	BY 91$ 91	BY 91$ 92	BY 91$ 93	BY 91$ 94	BY 91$ 95	BY 91$ 96	BY 91$ 97	BY 91$ 98	BY 91$ 99	BY 91$ Total FY91 - FY14
3.0	OPERATIONS & SUPPORT	$143,638	$285,045	$2,822,288	$4,031,124	$8,760,727	$11,531,386	$14,446,186	$17,811,896	$17,811,896	$329,073,771
3.1	OPERATIONS	$54,925	$198,310	$1,413,300	$2,861,595	$4,759,919	$6,390,415	$8,152,174	$9,897,358	$9,897,358	$192,090,926
3.1.1	OP PERSONNEL	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.1.2	OP TRAINING	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.1.3	MATERIAL CONSUMPTION	$54,454	$196,373	$1,400,576	$2,862,592	$4,720,406	$6,337,787	$8,085,467	$9,817,811	$9,817,811	$190,549,436
3.1.4	TRANSPORTATION	$470	$1,837	$12,724	$24,304	$39,513	$52,628	$66,708	$79,547	$79,547	$1,550,490
3.2	MAINTENANCE	$22,133	$86,835	$603,938	$1,161,229	$2,248,100	$3,004,223	$3,813,567	$4,632,173	$4,632,173	$89,694,023
3.2.1	ORG MAINTENANCE	$3,568	$13,933	$96,498	$184,319	$299,666	$399,133	$506,910	$600,287	$600,287	$11,758,913
3.2.1.1	OM PERSONNEL	$1,874	$7,319	$50,697	$96,826	$157,420	$209,671	$265,763	$316,917	$316,917	$6,177,150
3.2.1.2	OM TRAINING	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.2.1.3	OM MAINT MATERIAL	$282	$1,102	$7,634	$14,582	$23,708	$31,577	$40,925	$47,728	$47,728	$930,294
3.2.1.4	OM REPAIR MATERIAL	$1,411	$5,512	$38,172	$72,911	$118,539	$157,885	$200,123	$238,642	$238,642	$4,651,469
3.2.1.5	OM OTHER	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.2.2	INTER MAINTENANCE	$17,310	$67,597	$468,162	$894,227	$1,813,668	$2,426,842	$3,082,739	$3,758,326	$3,758,326	$72,662,084
3.2.2.1	IM PERSONNEL	$5,958	$23,266	$161,535	$307,781	$500,392	$666,485	$844,784	$1,007,583	$1,007,583	$19,635,400
3.2.2.2	IM TRAINING	$0	$0	$0	$0	$359,829	$490,437	$628,301	$831,459	$831,459	$15,613,370
3.2.2.3	IM MAINT MATERIAL	$447	$1,745	$12,088	$23,088	$37,537	$49,997	$63,372	$75,570	$75,570	$1,472,965
3.2.2.4	IM REPAIR MATERIAL	$10,727	$41,888	$290,104	$554,122	$900,095	$1,199,925	$1,520,932	$1,815,681	$1,815,681	$35,351,162
3.2.2.5	IM OTHER	$179	$698	$4,835	$9,235	$15,015	$19,999	$25,349	$30,228	$30,228	$589,186
3.2.3	DEPOT MAINTENANCE	$1,255	$5,305	$44,329	$84,683	$134,766	$178,248	$224,915	$270,560	$270,560	$5,273,026
3.2.3.1	DEPOT PERSONNEL	$394	$1,539	$24,026	$46,640	$70,093	$92,996	$117,149	$141,378	$141,378	$2,754,669
3.2.3.2	DEPOT TRAINING	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.2.3.3	DEPOT REPAIR MATERIAL	$565	$2,205	$15,269	$29,164	$47,416	$63,154	$80,049	$95,457	$95,457	$1,860,587
3.2.3.4	DEPOT OVH MATERIAL	$273	$1,469	$4,398	$8,664	$14,883	$19,466	$24,385	$29,748	$29,748	$580,245
3.2.3.5	DEPOT OTHER	$24	$92	$636	$1,215	$1,976	$2,631	$3,335	$3,977	$3,977	$77,524
3.3	PROGRAM MGMT	$0	$0	$0	$0	$150,000	$150,000	$150,000	$150,000	$150,000	$1,650,000
3.4	REPLEN SPARES	$0	$0	$0	$0	$1,692,708	$1,986,746	$2,332,365	$2,332,365	$2,332,365	$45,572,023
3.5	REFURBISHMENT	$66,800	$0	$0	$0	$0	$0	$0	$0	$0	$66,800

Exhibit I-2. SINCGARS ITT OPERATIONS AND SUPPORT ESTIMATE BY YEAR (BY91$) (WITHOUT RISK)

rules and assumptions used to perform this study. Section IV presents the detailed cost studies associated with each type of battery. Section V quantifies the potential cost savings associated with a mix of non-rechargeable and rechargeable batteries. Appendix A is an extract from the Solid Waste Disposal Act that sets forth the responsibilities of generators of hazardous waste. Appendix B provides a copy of a letter from the Environmental Protection Agency (EPA) to the Defense Logistics Agency (DLA) with regard to the disposal of LiSO2 batteries. Appendix C documents LiSO2 disposal packaging requirements. Appendix D documents Ni-Cad disposal packaging requirements.

II. TECHNICAL CHARACTERISTICS OF (ALTERNATIVE BATTERY) CHEMISTRIES

This section provides a general description of each type of battery chemistry considered, as well as the specifics associated with SINCGARS-suitable batteries. The chemistries considered are:

- Lithium-Sulfur Dioxide (LiSO2),
- Nickel-Cadmium (Ni-Cad),
- Sealed lead-acid (lead-acid), and
- Other Chemistries.

Exhibit II-1 summarizes the operational charcteristics of each battery type in an AN/PRC-119 SINCGARS manpack radio.

A. LITHIUM-SULFUR DIOXIDE (LiSO2) BATTERIES

The baseline battery for SINCGARS is the BA-5590/U non-rechargeable LiSO2 battery. Exhibit II-2 provides the specification sheet for one vendor's BA-5590/U battery. The primary advantages of the LiSO2 battery are:

- very high energy and power density,
- high rate discharge capabilities,
- excellent shelf life, and
- SINCGARS was designed to use the BA-5590 battery.

There are, however, significant disadvantages associated with the use of LiSO2 batteries. These include:

- The battery utilizes a non-resettable internal high temperature switch that renders the battery useless if the switch is tripped,
- The battery utilizes a non-resettable internal fuse that renders the battery useless if the fuse is blown,

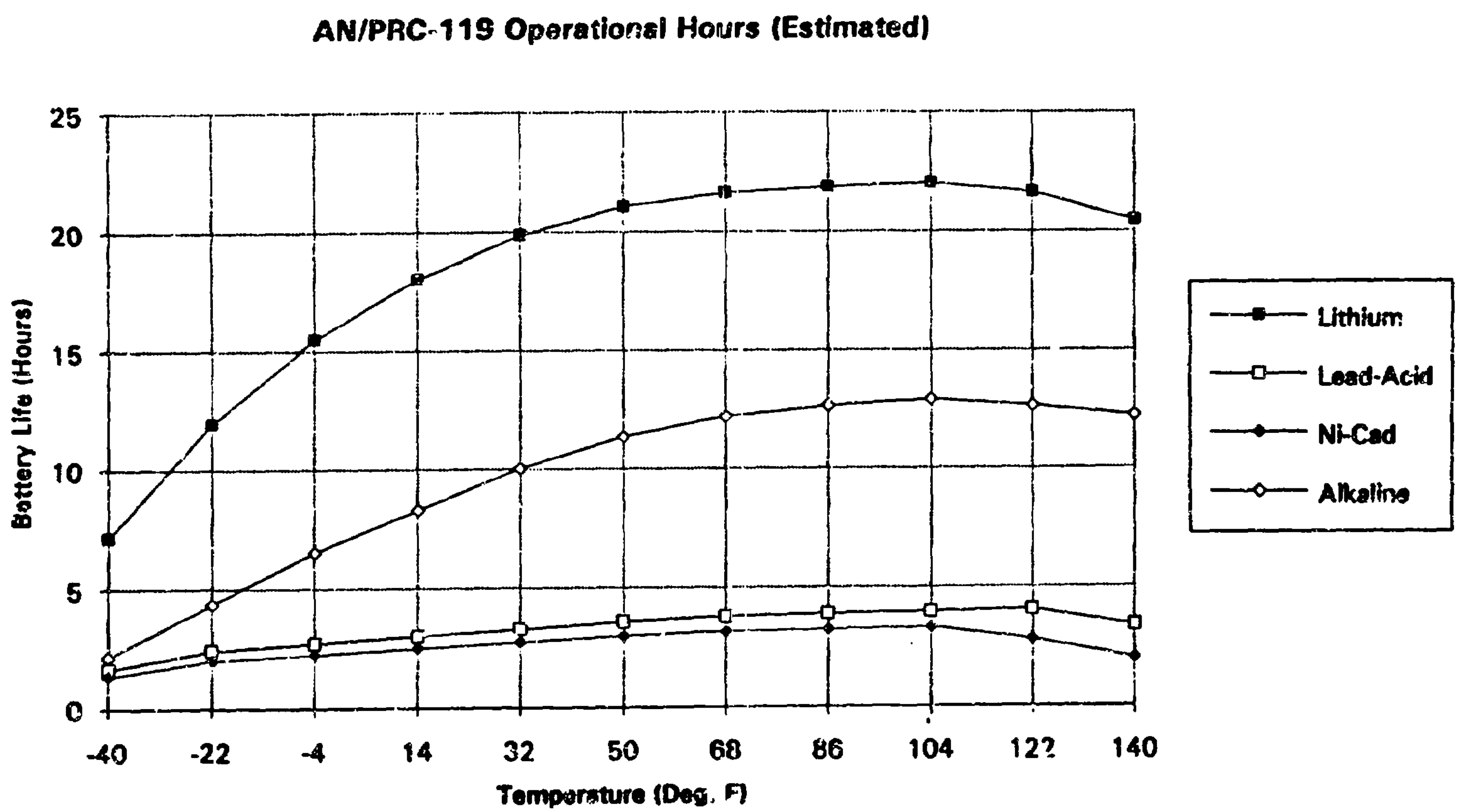


Exhibit II-1. COMPARISON OF BATTERY LIFE PER CYCLE

BA - 5590/U

LITHIUM SULFUR DIOXIDE PRIMARY BATTERY SYSTEM

NSN: 6135-01-036-3495

PHYSICAL SPECIFICATIONS

Weight (max):	2.25 lbs ; 1021 Grams
Dimensions:	Refer to Figure 1

Battery is packaged in a plastic case.

Tolerances are + 0.000, -0.063 (1.60mm) unless otherwise specified.

ELECTRICAL SPECIFICATIONS

Cell Complement: 10 cells connected in 2 groups of 5 cells in series; providing 2 nominal 12-volt sections at connector. These sections can be connected in series (for 24 volts), in parallel (for 12 volts), or used as two seperate 12-volt units.

Voltage:

Nominal:	12 or 24 volts
Max. (OCV)	15.25 or 30.5 volts
Average (@ 240 ma):	14 or 28 volts
Final:	10 or 20 volts

Rated Capacity (at 240 ma discharge):

70°F (21°C):	12 volts mode 14.4 Ah
	24 volts mode 7.2 Ah
-20°F (-29°C)	12 volts mode 9.5 Ah
	24 volts mode 4.75 Ah

Fuse. A slow blow 2.25 Amp non-replaceable fuse is incorporated in the negative leg of each series group of cells.

High Temperature Switch. A normally closed high temperature switch or thermal fuse is incorporated into each series leg of cells. It will open at 190° ± 5°F (88°C) and is non-resetable and non-replaceable.

Diode. A diode is incorporated into the positive leg of each series group of cells to prevent charging or flow of current into the battery.

Complete Discharge Device: A device consisting of a manually activated switch and resistors designed to discharge the battery to 0 Volts.

Mating Connector	ITT Cannon CA 110821-6
Military Specification:	MIL-B-49430A (ER)

TYPICAL APPLICATION

AN/PRC-104	Radio
KY-57 KY-65	Telephone Set
AN/PRC-119	Radio (Sincgars)
REMBASS	Remotely Monitored Battlefield Surveillance System
PLRS	Position Locator and Reporting System
RT-991	Buoy Radio
RT-1175	Buoy Radio

Inches	MM
0.031	0.79
0.063	1.60
0.734	18.64
0.750	19.05
2.450	62.23
4.400	111.76
5.000	127.00

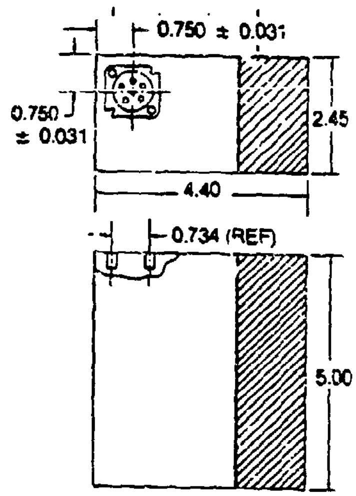


Figure 1: Outline Dimensions (Inches)

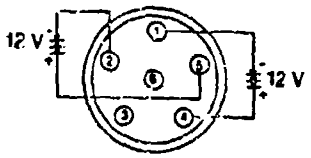


Figure 3: Connector Detail

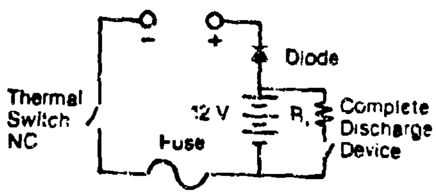


Figure 2: Wiring Schematic For Each Leg

Exhibit II-2. TECHNICAL CHARACTERISTICS OF BA-5590 LiSO2 BATTERY

FEDERAL and MILITARY SPECIFICATIONS

Meets requirements of Military specifications for Battery BA-5590/U, MIL-B-49430(ER), "Batteries, Non-rechargeable, Lithium Sulfur Dioxide", Specification Sheet MIL-B-49430/4(ER), e.g.

a. Capacity Tests at -20°F, 70°F, 130°F, Discharge Rate 2A
b. Storage Tests at 70°F, 130°F, 160°F
c. Safety Feature Tests
   (1) 300°F Temperature and Short Circuit Test
   (2) Forced Discharge Test
   (3) Leakage Test
d. Environmental Requirements

Vibration	Harmonic motion, 10-55 cps 0.03" amplitude
Shock	75 G acceleration
Altitude	50,000 feet
Storage Tests:	Up to 4 weeks at 160°F

HANDLING

Do not puncture, open or mutilate.
Cells are pressurized
Do not short circuit or charge
Do not expose to fire or temperatures above 160°F (71°C).
Cells may vent or explode if exposed to these conditions

SHIPPING

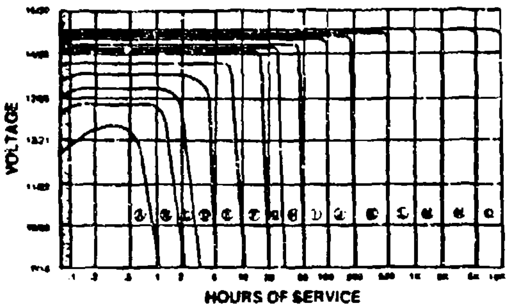
Meets requirements of Department of Transportation Exemption DOT-E-7052

DISPOSAL

Disposal of lithium batteries is regulated by the U.S Environmental Protection Agency

Battery design and specifications are subject to change without prior notice

BA-5590/U



Discharge Rate (ma.)
Ⓐ = 4230 Ⓓ = 1440 Ⓖ = 240 Ⓙ = 38 Ⓜ = 3.80
Ⓑ = 2700 Ⓔ = 720 Ⓗ = 150 Ⓚ = 15.2 Ⓝ = 1.52
Ⓒ = 2070 Ⓕ = 360 Ⓘ = 75 Ⓛ = 7.6 Ⓞ = 0.76

Figure 4: Typical Discharge Curves at 70°F (21°C): 24-volt mode (Double current values for 12-volt mode when sections are used in parallel.)

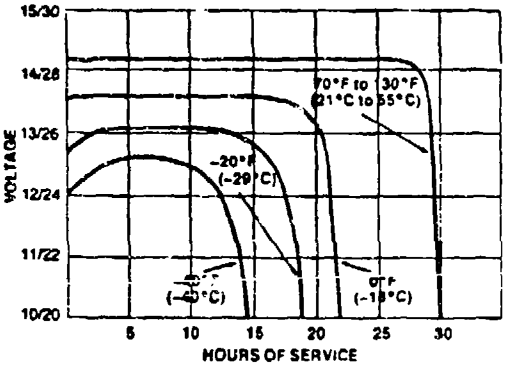


Figure 5: Typical Discharge Curves at: 240 ma (24-volt mode) 480 ma (12-volt mode when sections are in parallel.)

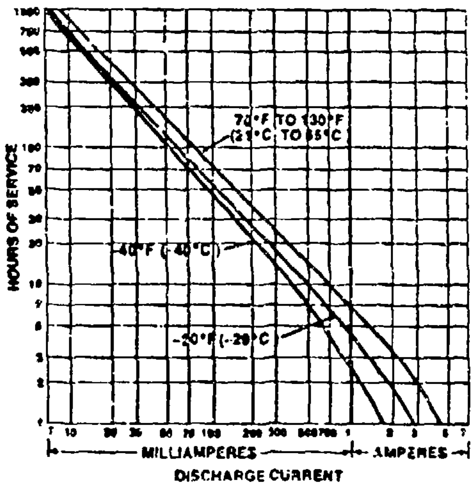


Figure 6: Service Life on Constant Current Discharge to 20 Volts (24-volt mode) (Double value of discharge current for 12-volt mode, when sections are used in parallel. End voltage is 10 volts)

Exhibit II-2. TECHNICAL CHARACTERISTICS OF BA-5590 LiSO2 BATTERY

- Due to its sealed construction and internal composition, the transportation of the battery may be subject to restrictions based on the number of batteries transported or the specific carrier, and

- There is only one company in the U.S. currently licensed by the Environmental Protection Agency (EPA) to dispose of LiSO2 batteries.

B. NICKEL CADMIUM BATTERIES

The rechargeable Ni-Cad battery that is suitable for SINCGARS applications is designated the BB-590/U. Exhibit II-3 provides an extract from the military specification for the battery. Its primary advantages are:

- Good shelf life, and

- Less expensive initial cost per battery than lead-acid.

The primary disadvantages are:

- low energy density,

- poor low temperature operation, and

- difficulty of disposal.

Used Ni-Cad batteries cannot be easily disposed of due to health concerns over their cadmium content.

C. SEALED LEAD-ACID BATTERIES

The rechargeable sealed lead-acid battery that is suitable for SINCGARS applications is designated the BB-490/U. Exhibit II-4 provides one manufacturer's technical description of the battery. Its primary advantages are:

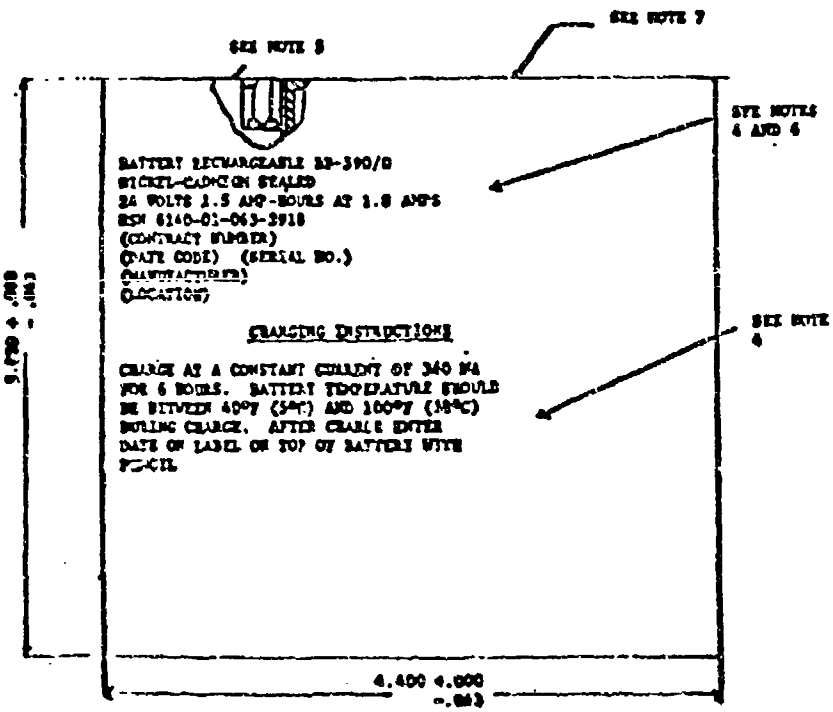
- Rechargeable via a broad array of charging means.

MILITARY SPECIFICATION SHEET

BATTERY, RECHARGEABLE, SEALED NICKEL CADMIUM BB-590/U

This specification sheet is approved for use by the Electronic Research and Development Command, Department of the Army, and is available for use by all Departments and Agencies of the Department of Defense.

The complete requirements for acquiring the sealed nickel cadmium rechargeable battery type described herein shall consist of this document and the latest issue of MIL-B-49436(ER).



INCHES	MM
.063	1.60
4.400	111.76
5.000	127.00

FIGURE 1. FRONT VIEW

Exhibit II-3. EXTRACT OF MILITARY SPECIFICATION FOR BB-590 Ni-CAD BATTERY

DRAWING NOTES

1. All dimensions in inches.

2. Tolerances on decimals: ± .031 inch.

3. Dimensioning shall be per USAS-Y14.5 Y14.5 1966.

4. Stencil (or equivalent) schematic, identification and charging instructions as shown. Color marking white.

5. Face of connector shall be flush to .031 below top of battery.

6. Manufacturer must fill in applicable information in parenthesis.

7. See top view on Figure 2.

8. Pressure relief valve shall be located under connector. It shall release gas before case damage is incurred.

9. For connector/battery interface see Figure 3.

10. Connector main keyway and pin 1 oriented over hole C.

11. Plug unused lettered holes with teflon bushings or equivalent per table I.

12. Lettered holes furnishing through passage of SC-C-179495 wires of table I shall be pre-fitted with neoprene rubber grommet of 50 ± 5 durometer with MIL-R-3065 to furnish water-tight seal around connector wires.

13. Pressure relief valve mounted in hole B has typical height of .42 from base on connector well.

14. .156 ± .002 Dia X .34 ± .02 Deep, for a 4-40 UNC-2A insert. Insert to be flush or below surface 2 places at A.

TABLE I. CONNECTOR WIRE COLOR CODE

HOLE C	HOLE D	HOLE E	HOLE F
BLACK/WHITE	BLACK	WHITE/RED	RED

Exhibit II-3. EXTRACT OF MILITARY SPECIFICATION FOR BB-590 Ni-CAD BATTERY (CONT'D)

MAGNUM

POWER SYSTEMS

BB-490/U

BATTERY SYSTEM BB-490/U (MPS 590)

SPECIFICATIONS

The battery system is constructed of unitary, non-liquid sealed lead acid rechargeable cells. The battery is free from any corrosive gas generation, is leak proof, maintenance free and not subject to any special handling requirements of DOT-E-7052 and codes of federal regulations volume 49, part 173.206; rated as a dry battery.

The battery system directly replaces U.S. Military issue BB-590 (Nicad) and BA-5590/U (lithium).

NOMENCLATURE

U.S. Military stock number NSN 6140-01-331-4013

PHYSICAL SPECIFICATIONS

Dimensions (inches +/- .02)

height	5.00"
length	4.40"
width	2.45"
weight	3.5 lbs.

ELECTRICAL SPECIFICATIONS

Cell Complement: 12 cells connected in 2 groups of 6 cells in series; providing 2 nominal 12-volt sections at connector. These sections can be connected in series (for 24 volts), in parallel (for 12 volts), or used as two separate 12 volt units.

Voltage:

Nominal:	12.0 volts or 24 volts
Max. (OCV)	14.80 or 29.60 volts

Capacity: 77°F (25°C)

12 Volt Connection	24 Volt Connection
20 hr. rate (190ma) 3.8AH	20 hr. rate (95ma) 1.9AH
10 hr. rate (360ma) 3.6AH	10 hr. rate (180ma) 1.8AH
5 hr. rate (700ma) 3.5AH	5 hr. rate (350ma) 1.75AH
1 hr. rate (2600ma) 2.6AH	1 hr. rate (1300ma) 1.30AH

Storage: 77°F (25°C)	Normal Operations:		
90% after 3 months	Discharge:	5°/122°F	-15°/50°C
80% after 6 months	Charge:	32°/104°F	0°/40°C
60% after 12 months	Storage:	5°/104°F	-15°/40°C

Charging: The 12/24 volt BB-490/U Sealed Lead Acid Rechargeable Battery is charged as two independent 12 volt units.
The batteries are charged by the MPS-AH6 charger (which is dedicated to charging the BB-490/U batteries) in conjunction with a compatible power supply. (MPS-CH2)
Batteries will normally receive 80% of depleted capacity within 1 hour and will be fully recharged in 4 hours.

Connector: ITT-Cannon CA110821-1/4 Type

continued on reverse

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Exhibit II-4. TECHNICAL CHARACTERISTICS OF BB-490 LEAD-ACID BATTERY

Typical Applications:

PRC 104	LST-5B
PRC-113	VRC-100
PRC-117	VRC-101
PRC-119	VRC-110
KY-57	PM-15
KY-67	PM-15A

Note: For additional equipment applications refer to:
ETD Laboratory
Power Source Division
ATTN: SLCET-PB

Fort Monmouth, NJ 07703-5000
(Tel no: (908) 544-4246; DSN 995-4246)
DOCUMENT: # A3154308 - January 1991

NSN STOCK NUMBERS

BB-490/U	Battery	6140-01-331-4013
BB-490/U Kit	Battery Kit	6140-01-331-4014
MPS-AH6	Charger	6130-01-331-4015
MPS-CH2	Transformer	6130-01-331-4016

DATA INFORMATION

BB-490/U Cost Comparisons in Operation vs BA 5590 Lithium

BB-490/U SLA Battery		BA-5590 Lithium Battery	
Unit Cost:	$279.00	Unit Cost:	$ 60.00
Recharge Capability:	500 Cycles	Recharge Capability:	None
Cost Per Usage:	$ 0.55	Cost Per Usage:	$ 60.00
Cost Per 500 Uses	$279.00	Cost Per 500 Uses	$30,000.00

Savings: $29,721.00*

*Does not include disposal costs est. at $28.00 per BA-5590 Lithium battery;
or 500 Lithium @ $28.00 = $14,000.00

FEATURES

1. CYCLES/ 200 to 1,000, depending on depth of discharge
2. Storage life up to 3 years at room temperature
3. Electrically isolated plastic battery case - no shorting
4. Absolutely NO MEMORY
5. Charging by either Constant Voltage/Constant Current
6. Resealing safety valve — under abusive overcharge
7. Excellent vibrational and mechanical strength
8. Safe operation usage in any position
9. Excellent recovery from overdischarge
10. Float life 8 to 10 years to 80% of rated capacity

SAMPLE OPERATION DATA

KY 57 Unit (Typical duty cycle)

4.3 Watts on Receive
6.0 Watts on Transmit
6.5 Watts - Wire Line

Average: 5.5 Watts = 2.29 ma C/15 = 8.07 Hrs of Operation

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Exhibit II-4. TECHNICAL CHARACTERISTICS OF BB-490 LEAD-ACID BATTERY (CONT'D)

- Fault-tolerant,
- Good high temperature operation, and
- Good shelf life.

The primary disadvantages are:

- low energy density, and
- poor low temperature operation

Although used lead-acid batteries cannot generally be disposed of in landfills due to health concerns over their lead and acid content, used lead-acid batteries can be fairly easily recycled. Currently, approximately 80% of automotive lead acid batteries are recycled, and a well established recycling business is in place. Therefore, the batteries can be disposed of by selling them to an authorized recycler.

D. OTHER BATTERY CHEMISTRIES

Two other potential chemistries were identified and analyzed: conventional alkaline non-rechargeable batteries and Nickel Metal-Hydride (NiMH) rechargeable batteries. Alkaline batteries exhibit performance between rechargeable batteries and LiSO2 batteries. Disposal of alkaline batteries is not highly regulated. The primary disadvantage of alkaline batteries is that they exhibit a dramatic falloff in energy capacity as temperatures drop. Due to this low temperature falloff and inability to identify a commercially available SINCGARS-compatible alkaline battery, this chemistry was excluded from further analysis.

NiMH batteries are rechargeable. NiMH batteries do not contain especially toxic chemicals or elements, and exhibit electrical properties generally similar to Ni-Cad batteries. The principal difference is that NiMH batteries are more energy dense (i.e., last longer) than either Ni-Cad or lead-acid batteries. NiMH batteries are just entering the commercial marketplace and technological improvements are being worked on along several dimensions

(e.g., energy density and recharge characteristics). Although NiMH batteries may be a viable or even preferable source of rechargeable battery power in the near to mid future, this chemistry was excluded from detailed analysis because no commercially available SINCGARS-compatible NiMH battery could be identified.

III. GROUND RULES AND ASSUMPTIONS

This section documents the ground rules and assumptions used in this study.

A. BATTERY COSTS

The ground rules and assumptions relevant to primary battery costs are listed below.

- Analysis limited to the following three battery types:

    - BB-5590 Lithium-Sulfur Dioxide (LiSO2),
    - BB-590 Nickel-Cadmium (Ni-Cad), and
    - BB-490 Sealed lead-acid (lead-acid).

- Two rechargeable batteries per portable or vehicular dismountable radio.

- LiSO2 battery cost and life identical to previous MCR USMC SINCGARS LCC estimate:

    - $45 per LiSO2 battery
    - 22 hour battery life

- Quantities and usage assumptions identical to previous MCR USMC SINCGARS LCC estimate:

    - Hours per radio type

        - Portable: 500 hrs/yr active forces, 125 hrs/yr reserve
        - Vehicular: 1,000 hrs/yr active forces, 250 hrs/yr reserve

    - Vehicular dismountable radios will use battery power 10% of the time.

- Distribution of radios: 75% to active duty forces, 25% to reserves.

- Quantities as per Addendum 1 to MCR USMC SINCGARS LCC estimate dated 04 October 1991

- Hold-Up Battery (HUB) costs are not affected by primary battery type or radio vendor (GD or ITT) and are, therefore, excluded from this analysis.

B. BATTERY CHARGERS

The ground rules and assumptions relevant to the cost of the battery changes are listed below.

- One charger for each portable radio.

- No chargers for vehicular dismountable radios (batteries recharged from vehicle's electrical system).

- Battery chargers replaced when rechargeable batteries replaced.

C. DISPOSAL

The ground rules and assumptions relevant to disposal costs are listed below.

- All waste generated at Camp Lejeune, North Carolina.

- Transportation in accordance with federal/EPA regulations:

  - licensed hazardous waste hauler, and
  - manifested load.

- Replacement rechargeable battery quanitity identical to disposal quantity.

- Disposal transportation cost per truckload identical for LiSO2 and Ni-Cad batteries.

- Waste treatment in accordance with federal/EPA regulations.

IV. DETAILED COST STUDY

There are four basic cost elements potentially associated with the life cycle cost of each battery chemistry:

- the cost of the batteries themselves,
- charger costs (rechargeable chemistries only),
- disposal transportation costs, and
- waste treatment costs.

Total battery-related annual costs were estimated for each of the three chemistries, assuming that all USMC SINCGARS demand would be met with a single battery type. An average hourly operational cost was also estimated for each alternative. Section V of this cost study uses the results of this section to quantify the potential cost savings that could accrue to the USMC by using a mix of non-rechargeable and rechargeable batteries. The following subsections describe how each cost element for each chemistry was estimated. Exhibit IV-1 provides a summary of the costs of each of the three battery chemistries by cost element. The basis for those costs is documented in the body of this section.

The fundamental factor that drives the cost of all three battery chemistries is the annual battery-powered operational requirement. Since this is common to all three alternatives, the derivation of the annual operational requirement is described first.

A. ANNUAL BATTERY-POWERED OPERATIONAL REQUIREMENT

The total battery-related operations cost is contained in Work Breakdown Structure (WBS) element 3.1.3, Material Consumption, in MCR's SINCGARS LCC Estimate, Addendum 1, dated 04 October 1992. The estimated total material consumption cost is approximately $191 million in Base Year 1991 dollars (BY91$), or approximately 58% of the total O&S cost for USMC SINCGARS. The Material Consumption WBS element represents

Annual USMC SINCGARS Cost	BA-5590 LiSO2	BB-590 Ni-Cad	BB-490 Lead-Acid
Operations	$9,515,301	$1,514,053	$1,367,009
- Primary Batteries	$9,515,301	$898,491	$1,231,334
- Chargers	$0	$615,563	$135,675
Disposal	$2,881,710	$55,891	$11,944
- Transportation	$27,120	$2,260	$452
- Treatment	$2,854,590	$53,631	$11,492
TOTAL	$12,397,011	$1,569,945	$1,378,954
Operational Hours	4,651,925	4,651,925	4,651,925
Cost Per Hour	$2.66	$0.34	$0.30

Exhibit IV-1. SUMMARY OF DETAILED COST ESTIMATE

the sum of primary battery costs and Hold-Up battery (HUB) costs and is identical for both ITT and GD.

The annual battery-powered operational requirement was separately calculated for active and reserve forces and the resulting two values were summed to arrive at the total estimated USMC SINCGARS annual battery-powered operational requirement. The first column of Exhibit IV-2 identifies the nomenclature of the various SINCGARS radios that will be fielded by the USMC in the steady-state O&S period which begins in FY98. The second column identifies the number of each type of radio assigned to each respective force. These quantities were derived by allocating 75% of the USMC SINCGARS general fielding procurement to active forces and the remaining 25% of the procurement to reserve forces.

The third column of Exhibit IV-2 identifies the estimated annual usage for each radio/force combination based on the USMC operational scenario. The fourth column identifies the extent to which each type of radio will use battery power. Manpack (i.e., AN/PRC-119A) radios will operate solely from batteries. The two dismountable vehicular radio types (AN/VRC-88A and AN/VRC-91A) were previously estimated to use battery power for 10% of the time. The last column represents the estimated total number of battery-powered operational hours per year per radio/force combination. The values in the last column were calculated by multiplying the radio quantity by the hours per year by the battery usage factor. These values were then summed to arrive at the active forces subtotal and the reserve forces subtotal and finally the total estimated USMC SINCGARS annual battery-powered operational requirement, which is approximately 4.7 million hours per year. This value was used to estimate the LCC costs associated with each of the three rechargeable battery scenarios.

Active	Radio Qty	Hours per Yr.	Bat. Use	Battery Hrs. per Yr.
AN/PRC-119A	7,537	500	100%	3,768,500
AN/VRC-88A	3,110	1,000	10%	311,000
AN/VRC-89A	1,361	1,000	0%	0
AN/VRC-90A	262	1,000	0%	0
AN/VRC-91A	2,145	1,000	10%	214,500
AN/VRC-92A	2,452	1,000	0%	0
Active Subtotal				4,294,000
Reserve	**Hours Qty**	**Battery per Yr.**	**Bat. Use**	**Hrs per Yr.**
AN/PRC-119A	2,513	125	100%	314,125
AN/VRC-88A	1,037	250	10%	25,925
AN/VRC-89A	454	250	0%	0
AN/VRC-90A	88	250	0%	0
AN/VRC-91A	715	250	10%	17,875
AN/VRC-92A	818	250	0%	0
Reserve Subtotal				357,925
GRAND TOTAL				4,651,925

Exhibit IV-2. DERIVATION OF ANNUAL USMC SINCGARS BATTERY-POWERED OPERATIONAL REQUIREMENT

B. BA-5590 LITHIUM SULFUR DIOXIDE (LiSO2) BATTERY COSTS

The O&S and disposal costs of the LiSO2 alternative are represented in the following discussion. O&S-related costs (batteries only for this alternative - no chargers) are described separately from disposal costs (disposal transportation and waste treatment). Total annual LiSO2 battery-related costs (operations costs plus disposal costs) are estimated at approximately $12.4 million. Another way of expressing this cost is that each LiSO2 battery powered operational hour costs $2.66.

1. LiSO2 O&S Costs

Since the LiSO2 battery is non-rechargeable, the only O&S-related costs are associated with the cost of the batteries themselves. As previously discussed, the USMC will operate portable and vehicular dismountable radios from battery power approximately 4.7 million hours per year. The battery unit cost used in this study was $45 and each battery was esti[illegible]d to last 22 hours. Both of these values were obtained from the Army SINCGARS Baseli[illegible] Cost Estimate (BCE). The Army BCE derived these values based on historical data on analogous systems and the technical characteristics of SINCGARS. The annual LiSO2 battery O&S cost in the steady state period is represented by the following equation:

Annual LiSO2 O&S. Cost = 4.7 million hours per year / 22 hours per battery * $45 per battery = $9.5 million

2. LiSO2 Disposal Costs

The Environmental Protection Agency (EPA) classifies LiSO2 batteries as hazardous waste based on the following characteristics:

- LiSO2 batteries may form potentially explosive hydrogen gas when mixed with water, and
- LiSO2 batteries are capable of violent rupture or reaction.

Appendix A is an extract from the Solid Waste Disposal Act that describes the responsibilities of generators of hazardous waste. Appendix B provides a copy of a letter from the EPA to the Defense Logistics Agency (DLA) that elaborates on the potential hazards associated with the disposal of LiSO2 batteries.

There is only one company in the United States that is currently licensed by the EPA to dispose of LiSO2 batteries, Battery Disposal Technology, Inc. (BDT), located in Clarence, New York. Therefore, there are both disposal transportation costs and waste treatment (destruction/deactivization) costs associated with LiSO2 batteries. Each of these cost elements is described and quantified below.

a. LiSO2 Transportation Costs

For purposes of this study, it was assumed that all depleted LiSO2 batteries would be transported via truck from Marine Corps Base, Camp Lejeune to BDT in New York. Prior to acceptance by the trucking firm, USMC personnel must ensure that the batteries are fully discharged and packed into sealed 55-gallon drums in such a manner that they will not come into electrical contact with each other. Appendix C identifies BDT's packaging requirements in more detail. The trucking firm will then certify the contents of the truck, transport the material to BDT, and obtain a certificate from BDT stating that the full load was delivered. This process is called manifesting and is required for the transportation of hazardous waste. (See Appendix A, Extract from Solid Waste Disposal Act.)

A verbal quote of $2,260 per truckload per trip was obtained from Chemical Waste Management, Inc. for transporting the batteries from Camp Lejeune to BDT. Each truckload would be comprised of approximately 65 loaded 55-gallon drums weighing approximately 600 pounds each.

In order to estimate transportation costs, the total annual weight of depleted LiSO2 batteries was first estimated from the annual operational requirement of 4.7 million hours previously derived. The number of batteries was then calculated based on average battery life and multiplied by the weight of each battery to arrive at the weight of the batteries that would be transported for disposal. The following equation was used:

Transportation Wt. = 4.7 million hours per year / 22 hours per battery * 2.25 pounds per battery = 480,000 pounds per year

Since the maximum load per truck is rated at 40,000 pounds, this is equivalent to approximately 12 trips per year, or one each month. Therefore, the total annual transportation cost would be 12 times $2,260, or $27,120 per year.

b. LiSO2 Waste Treatment Costs

The cost to treat the LiSO2 battery waste was estimated from a verbal quote from BDT. BDT currently charges $6.00 per pound to treat depleted LiSO2 batteries. BDT treats LiSO2 batteries by crushing them in an explosion-proof room, activating the lithium in a controlled manner, and then forming inert metallic bars by mixing the remaining material with a filler.

As derived in the previous subsection, approximately 480,000 pounds of LiSO2 battery waste would require treatment per year. At $6 per pound, the total annual waste treatment costs are expressed in the following formula:

Waste Treatment Cost = 480,000 pounds of waste * $6.00 per pound for treatment = $2.9 million per year

C. BB-590 NICKEL-CADMIUM (NI-CAD) BATTERY COSTS

The O&S and disposal costs of the Ni-Cad alternative are represented in the following discussion. O&S-related costs (batteries and chargers) are described separately from disposal

costs (transportation and treatment). Total annual Ni-Cad battery-related costs are estimated at approximately $1.6 million. Another way of expressing this cost is that each Ni-Cad battery powered operational hour costs $0.34.

1. Ni-Cad O&S Costs

Since Ni-Cad batteries are rechargeable, both of the following operations-related cost elements apply: the cost of the batteries themselves and the cost of the chargers. The manner in which each of these cost elements was estimated is provided in the following two subsections.

a. Ni-Cad Primary Battery Costs

As previously discussed, the USMC will operate portable and vehicular dismountable radios from battery power approximately 4.7 million hours per year. The number of Ni-Cad batteries that the USMC would have to purchase annually if Ni-Cad batteries were used exclusively was estimated based on the following parameters:

- battery life per charge,
- the number of batteries per radio,
- the number of cycles per battery, and
- the cost per battery.

(1) Battery Life Per Charge

The first step in estimating the costs of the Ni-Cad scenario was to estimate the number of hours that a fully charged BB-590 Ni-Cad battery will power a SINCGARS radio. The battery life per charge for the BA-590 Ni-Cad battery was obtained by adjusting the manufacturer's claimed life which was judged to represent ideal conditions. The AN/PRC-119 was selected because it represents the overwhelming majority of the battery-powered operational requirement. Vendor information on the BA-5590 LiSO2

battery indicates that the maximum claimed battery life is approximately 33 hours at room temperature. The Army's analysis of LiSO2 battery life in SINCGARS radios indicated that, on average, the battery will actually power the radio for approximately 22 hours. Therefore, the Army estimates that actual life will be 2/3 of the vendor's claim. This 2/3 factor was applied to the effective vendor's claim of 6 hours per fully charged BB-590 Ni-Cad battery to arrive at the 4 hour lifespan used in this study. This life-per-cycle value was judged to more closely approximate probable USMC experience.

(2) Number of Batteries per Radio

It was then assumed that each portable or vehicular dismountable radio would be provided with two batteries. One battery would be in the radio, and the second would be in the charger. Since the battery can be recharged in less than four hours (depending on its state of discharge), this scenario would always provide for an available fully charged battery (assuming that the recharger was nearby and had a source of power).

(3) Number of Cycles per Battery

One of two additional factors may drive the actual number of batteries required to provide the required energy requirements for USMC SINCGARS: cycle life or float life. Cycle life refers to the maximum number of times a battery can be charged, discharged, and recharged while still providing at least 80% of the original performance. In the case of Ni-Cad batteries, claimed cycle life ranges from about 250 to 500. The value at the low end of the claimed range (250 cycles) was selected based on the expectation of relatively severe USMC usage. The difference in cycle life is primarily driven by differing assumptions with regard to discharge depth, discharge rate, and ambient temperature.

Float life is the second factor that may limit battery life. Float life refers to the maximum time that a battery can be held at a fully charged state via trickle charging. For Ni-Cad batteries, claims for float life range from 5 to 10 years. The failure mechanism is simply that the chemicals inside the battery inevitably build up and eventually insulate the battery from itself, rendering it incapable of holding a charge. There was a definite consensus that USMC personnel would not comply with ideal practice with regard to discharging, recharging, or operation in moderate environmental conditions and that a year float life would probably be more representative of USMC experience. Detailed analysis was then performed to determine if cycle life or float life was the limiting factor.

In order to determine if the limiting factor on USMC SINCGARS battery life was cycle life or float life, the battery usage process was modeled in more detail. The annual usage rate per radio type for the active and reserve forces was obtained from the USMC SINCGARS LCC estimate. The percentage of time that each radio would use battery power was also taken from that study. By multiplying the annual operations hours by the battery usage ratio, the number of battery cycles per year per radio was estimated. For example, for the PRC-119 radios used by the active forces, the annual operations hours were previously estimated at 500. Since the PRC-119 always uses battery power, the battery usage factor is 100%. (The battery usage factor for the two dismountable radios, AN/VRC-88A and AN/VRC-91A, is 10%.) Therefore, each active duty AN/PRC-119 radio would require 125 Ni-Cad battery recharge cycles per year, or 63 per battery if two batteries are assigned to the radio.

Exhibit IV-3 is a printout of the spreadsheet that was developed to resolve the cycle life/float life issue. The first column provides the nomenclature of all of the SINCGARS radios which will be used by the USMC. The list of radio types is repeated

Active	Hours Per Year	Battery Use Pct.	Bat. Hrs./ Yr.	Bat. Cyles/ Yr.	Cylces/ Yr./ Batt.	Cycles/ Bat./ Float	Radio Qty.	Bat. Pwrd. Hrs./Yr.	Pct. of Total	Weighted Average Cycles/Bat.
PRC-119A	500	100%	500	125	63	250	7,537	3,768,500	81%	203
VRC-88A	1,000	10%	100	25	13	50	3,110	311,300	7%	3
VRC-89A	1,000	0%	0	0	0	0	1,361	0	0%	0
VRC-90A	1,000	0%	0	0	0	0	262	0	0%	0
VRC-91A	1,000	10%	100	25	13	50	2,145	214,500	5%	2
VRC-92	1,000	0%	0	0	0	0	2,452	0	0%	0
Active Total							16,867	4,294,000		
Reserve										0
PRC-119A	125	100%	125	31	16	63	2,513	314,125	7%	4
VRC-88A	250	10%	25	6	3	13	1,037	25,925	1%	0
VRC-89A	250	0%	0	0	0	0	454	0	0%	0
VRC-90A	250	0%	0	0	0	0	88	0	0%	0
VRC-91AVR	250	10%	25	6	3	13	715	17,875	0%	0
C-92A	250	0%	0	0	0	0	818	0	0%	0
Rsv. Total							5,625	357,925		
Grand Total							21,674	4,651,925		213

Exhibit IV-3. DERIVATION OF WEIGHTED AVERAGE CYCLES PER BATTERY VALUE

vertically because active force radios were treated separately from reserve force radios. The second column of the exhibit provides the total expected operational hours per year for each radio type for both active and reserve forces, and the third column identifies the degree to which each radio would use battery power. The hours per year values in the second column were multiplied by the battery use percent values in the third column to estimate the battery-powered operational requirement for each radio/force combination. This result was then divided by the battery life per charge (4 hours) to arrive at the estimated number of battery cycles per year for each radio/force combination. This number, in turn, was divided by two batteries per radio to estimate the number of cycles per individual battery. Then the number of charge cycles per battery per year was multiplied by the anticipated float life (4 years) to identify the number of times each battery would be charged if the battery's life was limited by cycle life and not float life.

As can be seen from the column titled "Cycles/Battery/Float" column in the exhibit (Column #7), float life is more of a constraint to the USMC than is cycle life. For example, it is estimated that each of the two batteries assigned to a specific AN/PRC-119 radio used by the reserve forces would only be recharged 63 times in 4 years.

Once it was determined that float life and not cycle life was the limiting factor with regard to USMC SINCGARS, a weighted average cycles per battery per float life value was derived to simplify subsequent analysis. The last four columns in the exhibit identify the number of radios of each type in the steady state period used by the active and reserve forces, the battery-powered operational hours per radio/force combination, the percent of the total represented by each combination, and the weighted average. As can be seen at the bottom right of the exhibit, the weighted average is approximately 213 charge cycles per battery per float life.

(4) Cost Per Battery

The remaining piece of data is cost per battery. A verbal quote of $164.18 per BB-590 Ni-Cad battery was obtained from Bren-Tronics.

The remainder of the analysis is relatively simple. The number of batteries bought per year was calculated by starting with the annual battery-powered operational requirement and dividing by the hours per cycle to arrive at the number of battery cycles per year. This value was then divided by the average number of cycles per battery to arrive at the number of batteries, which was then multiplied by the battery unit cost to estimate the operations-related primary battery costs for USMC SINCGARS. The formula follows:

Annual Ni-Cad Battery Cost = 4.7 million hours per year / 4 hours per battery / 213 cycles per battery * $164.18 per battery = $0.9 million per year

b. Ni-Cad Charger Costs

The cost of chargers for the Ni-Cad scenario was based on a mix of engineering assessments and vendor quotes. The cost of Ni-Cad chargers was calculated from three basic inputs:

- Cost per charger,
- Charger life, and
- Number of chargers required.

Chargers were quoted at $245 each from Bren-Tronics. It was assumed that each portable radio would require a charger. Chargers were not estimated for dismountable radios based on an assumption that the batteries would be recharged off the vehicle's existing electrical system. The total number of USMC SINCGARS portable radios in the steady state period is 10,050. It was also assumed that rechargers would be replaced

at the end of the battery's float life, or every four years. Therefore, the total number of portable radios was divided by 4 to arrive at the estimated number of chargers that would be bought per year. The following equation was used:

Annual Ni-Cad charger cost = 10,050 portable radios / 4 year life per charger * $245 per charger = $0.6 million per year.

6. Ni-Cad Disposal Costs

The EPA classifies Ni-Cad batteries as hazardous waste. The EPA's concern is primarily over cadmium because it is a carcinogen. Due to these regulatory and health concerns, spent Ni-Cad batteries cannot generally be disposed of in landfills and must be recycled or otherwise neutralized. As with LiSO2 batteries, there is only one Ni-Cad battery recycling company in the United States that is currently licensed by the EPA to recycle Ni-Cad batteries, the International Metals Reclamation Company, Inc. (INMETCO). INMETCO is located in Ellwood City, Pennsylvania and utilizes the reclaimed metals from the batteries to manufacture stainless steel or as stabilized waste which is used as ballast for railroad beds. Appendix D sets forth INMETCO's battery processing conditions.

There are both transportation costs and treatment (destruction/deactivization) costs associated with Ni-Cad batteries. Each of these cost elements is described below.

a. Ni-Cad Transportation Costs

For purposes of this study, it was assumed that all depleted Ni-Cad batteries would be transported via truck from Marine Corps Base, Camp Lejeune to INMETCO in Pennsylvania. Prior to acceptance by the trucking firm, USMC personnel must ensure that the batteries are fully discharged and packed into sealed 55-gallon drums in such a manner that they will not come into electrical contact with each other. The trucking firm will then certify the contents of the truck, transport the material to INMETCO, and obtain

a certificate from INMETCO stating that the full load was delivered. This manifesting process is required for the transportation of hazardous waste.

Because the regulations pertaining to the transportation of depleted Ni-Cad batteries and LiSO2 batteries are similar, and because both BDT and INMETCO are located in the same general region, it was assumed that the transportation cost per load would be identical for both types of batteries. Therefore, the verbal quote of $2,260 per truckload per trip which was obtained from Chemical Waste Management, Inc. for transporting LiSO2 batteries from Camp Lejeune to BDT was used as a starting point in estimating the transportation costs associated with the disposal of depleted Ni-Cad batteries. Each truckload would be comprised of approximately 65 loaded 55-gallon drums weighing approximately 600 pounds each.

In order to estimate transportation costs, the total annual weight of depleted Ni-Cad batteries was estimated from the annual battery procurement requirement previously calculated. It was assumed that the inflow of new batteries would be equivalent to the outflow of expended batteries. The annual disposal weight was calculated by multiplying the number of batteries disposed of per year by the weight of each battery. The following equation was used:

Annual Ni-Cad Waste = 4.7 million hours per year / 4 hours per battery / 213 cycles per battery * 4 pounds per battery = 22,000 pounds per year

Since the maximum load per truck is rated at 40,000 pounds, this is equivalent to approximately 1 trip per year. The cost per trip was quoted at $2,260; therefore, the disposal transportation cost is estimated at $2,260 per year.

b. Ni-Cad Waste Treatment Costs

The cost to treat the Ni-Cad battery waste was estimated from a verbal quote from INMETCO. INMETCO charges $2.45 per pound for treatment costs. INMETCO treats Ni-Cad batteries by crushing them and then transferring the waste into a high temperature furnace. After the material is melted and partially purified it is cooled to form a non-toxic solid.

As derived in the previous subsection, approximately 22,000 pounds of Ni-Cad battery waste would require treatment per year. At $2.45 per pound, the total annual waste treatment costs are expressed in the following formula:

Waste Treatment Cost = 22,000 pounds of waste * $2.45 per pound for treatment
= $54,000 per year

D. BB-490 SEALED LEAD-ACID BATTERY COSTS

The O&S and disposal costs of the lead-acid alternative are represented in the following discussion. O&S-related costs (batteries and chargers) are described separately from disposal costs (transportation and treatment). Total annual lead-acid battery-related costs (operations plus disposal) are estimated at approximately $1.4 million. Another way of expressing this cost is that each lead-acid battery powered operational hour costs $0.30.

1. Lead-Acid O&S Costs

Since lead-acid batteries are rechargeable, there are two O&S cost elements: the cost of the batteries themselves and the cost of the chargers. The manner in which each of these cost elements was estimated is provided in the following two subsections.

a. Primary Lead-Acid Battery Costs

As discussed, the USMC will operate portable and vehicular dismountable radios from battery power approximately 4.7 million hours per year. The

number of lead-acid batteries that the USMC would have to purchase if lead-acid batteries were used exclusively was then estimated based on the following:

- battery life per charge,
- number of batteries per radio,
- number of cycles per battery, and
- cost per battery.

The battery life per charge for the BB-490 lead-acid battery was obtained by adjusting the manufacturer's claimed life which was judged to represent ideal conditions. The effective manufacturer's claim of 6 hours per charge in a typical SINCGARS application was adjusted based on the ratio between the claimed LiSO2 battery life and the Army's analysis. This ratio is approximately 2/3; therefore, the claimed life per lead-acid battery was multiplied by 2/3 to obtain 4 hours per charge. This life-per-cycle value was judged to more closely approximate probable USMC experience.

It was then assumed that each portable or vehicular dismountable radio would be provided with two batteries. One battery would be in the radio, and the second would be in the charger. Since the battery can be recharged in less than four hours, this scenario would always provide for an available fully charged battery (assuming that the recharger was nearby and had a source of power).

The next step was to estimate the number of cycles per battery. The number of cycles per battery may be limited by one of the following two basic factors: degeneration of the battery's internal components caused by the charge-discharge-recharge process, termed cycle life; and the degeneration simply caused by time and fluctuating environmental conditions such as temperature, humidity, and mechanical shock, termed float life. The claimed maximum life for lead-acid batteries is in the range of 8 to 10 years or

approximately 400 cycles, whichever comes first. Discussions with a number of technical representatives from lead-acid battery vendors indicated that float life is fairly sensitive to discharge characteristics, environmental conditions, and recharging practice. There was a definite consensus that USMC personnel would not comply with ideal practice in any of these three areas and that a 4 year float life would probably be more representative of USMC experience. Detailed analysis was then performed to determine if float life or cycle life was the limiting factor.

The previous discussion with respect to this issue and Ni-Cad batteries concluded that float life was the limiting factor and that the weighted average number of cycles per battery would be approximately 213. The relatively minor differences between Ni-Cad and lead-acid batteries with respect to float life and cycle life indicated that the 213 cycle value would also fairly represent USMC experience with lead-acid batteries. Therefore, the 213 cycle value was used in the subsequent lead-acid-specific analysis.

The remaining piece of data is cost per battery. A written quote of $225 per BB-490 lead-acid battery was obtained from Magnum Power Systems, Inc.

The remainder of the analysis is relatively simple. The number of batteries bought per year was calculated by starting with the annual battery-powered operational requirement and dividing that by the hours per cycle to arrive at the number of battery cycles per year. This value was then divided by the average number of cycles per battery to arrive at the number of batteries, which was then multiplied by the battery unit cost to estimate the O&S-related primary battery costs for USMC SINCGARS. The formula follows:

Annual lead-acid Battery Cost = 4.7 million hours per year / 4 hours per battery / 213 cycles per battery * $225 = $1.2 million per year

b. Lead-Acid Charger Costs

The cost of chargers for the lead-acid scenario was based on a mix of engineering assessments and vendor quotes. The cost of lead-acid chargers was calculated from the following three basic inputs:

- Cost per charger,
- Charger life, and
- Number of chargers required.

Chargers were quoted at $54 from Magnum Power Systems, Inc. It was assumed that each portable radio would require a charger. Chargers were not estimated for dismountable radios based on an assumption that the batteries would be recharged off the vehicle's existing electrical system. The total number of USMC SINCGARS portable radios in the steady state period is 10,050. It was also assumed that rechargers would be replaced at the end of the battery's float life, or every four years. Therefore, the total number of portable radios was divided by 4 to arrive at the estimated number of chargers that would be bought per year. The following equation was used:

Annual lead-acid charger cost = 10,050 portable radios / 4 year life per charger * $54 = $0.1 million per year.

2. Lead-Acid Disposal Costs

As with the LiSO2 and Ni-Cad batteries, the EPA classifies lead-acid batteries as hazardous waste. The EPA's concern is primarily over their lead content because lead presents a potential health hazard. Due to these regulatory and health concerns, spent Lead-Acid batteries can not generally be disposed of in landfills and must be recycled. Despite this regulatory classification, it is much easier to dispose of Lead-Acid batteries than to dispose of LiSO2 or Ni-Cad batteries. This is due to the fact that an active automotive battery

recycling industry is in place which recycles approximately 80% of all disposed automotive lead-acid batteries. Therefore, the USMC would have a choice of disposers, probably in or near the local community.

There are both transportation costs and treatment (destruction/deactivization) costs associated with lead-acid batteries. Each of these cost elements is described below.

a. Lead-Acid Transportation Costs

For purposes of this study, it was assumed that all depleted lead-acid batteries would be transported via truck from Marine Corps Base, Camp Lejeune to a local recycler. The trucking firm will certify the contents of the truck, transport the material to the recycling facility, and obtain a certificate stating that the full load was delivered. This manifesting process is required for the transportation of hazardous waste.

Because lead-acid batteries may be disposed of in a variety of locations, the previously used cost per truck trip ($2,260) was divided by five on the assumption that the local recycling center would be one-fifth of the distance from Camp Lejeune to the northeast. Each truckload would be comprised of approximately 65 loaded 55-gallon drums weighing approximately 600 pounds each. The next step was to estimate the number of trips per year.

In order to estimate transportation costs, the total annual weight of depleted lead-acid batteries was estimated from the annual battery procurement requirement previously calculated. It was assumed that the inflow of new batteries would be equivalent to the outflow of expended batteries. The annual disposal weight was calculated by multiplying the number of batteries disposed of per year by the weight of each battery. The following equation was used:

Annual lead-acid Waste = 4.7 million hours per year / 4 hours per battery / 213 cycles per battery * 3.5 pounds per battery = 19,000 pounds per year

Since the maximum load per truck is rated at 40,000 pounds, this is equivalent to approximately 1 trip per year. The cost per trip to the northeast was quoted at $2,260, and this value was divided by five because the distance to a lead-acid recycler should be relatively short. Therefore, the disposal transportation cost is estimated at $452 per year.

b. Lead-Acid Waste Treatment Costs

The cost to treat the lead-acid battery waste was estimated from data obtained from the Defense Reutilization and Marketing Office (DRMO) of the Defense Logistics Agency (DLA). Based on a review of several lead-acid disposal contracts, DRMO cited a typical disposal cost of $0.60 per pound. The lead from the batteries is used in the manufacture of new batteries and the remaining lead-acid components can be safely disposed of after proper treatment.

As derived in the previous subsection, approximately 19,000 pounds of lead-acid battery waste would require treatment per year. At $0.60 per pound, the total annual waste treatment costs are expressed in the following formula:

Waste Treatment Cost = 19,000 pounds of waste * $0.60 per pound for treatment = $11,500 per year

V. TRADE-OFF ANALYSIS

The previous section documented the basis for annual USMC SINCGARS primary battery and battery-related costs assuming that the USMC would rely exclusively on only one of the three alternative battery chemistries (LiSO2, Ni-Cad, or lead-acid). This section documents the potential cost savings and benefits associated with the following two more realistic scenarios:

- a mix of LiSO2 and Ni-Cad batteries, and
- a mix of LiSO2 and lead-acid batteries.

A. LISO2/NI-CAD MIX

Exhibit V-1 quantifies the total annual USMC SINCGARS primary battery and primary battery-related costs arising from a mix of LiSO2 and Ni-Cad batteries. The mix ranges from 100% reliance on LiSO2 batteries to 0% reliance on LiSO2 batteries (i.e., 100% reliance on Ni-Cad batteries). For example, if the USMC relied on LiSO2 batteries to meet 50% of the annual operational hour requirement, then the remaining 50% of the demand would be met with rechargeable Ni-Cad batteries. In this case, the annual LiSO2 cost would be approximately $6.2 million and the annual Ni-Cad cost would be an additional $0.8 million for a total cost of approximately $7 million, or a savings of approximately $5.4 million per year relative to 100% use of LiSO2 batteries.

The benefits that could accrue to the USMC by using a mix of LiSO2 and Ni-Cad batteries extends beyond potential cost savings. The primary additional benefit is the disposal issue. With a mix of batteries, the USMC would be in a better position to adjust the mix not only with regard to operational considerations, but with regard to changes in EPA regulations or with regard to changing pricing or acceptance policies at BDT. Other potential benefits include a reduced overall battery demand on the USMC supply system and the

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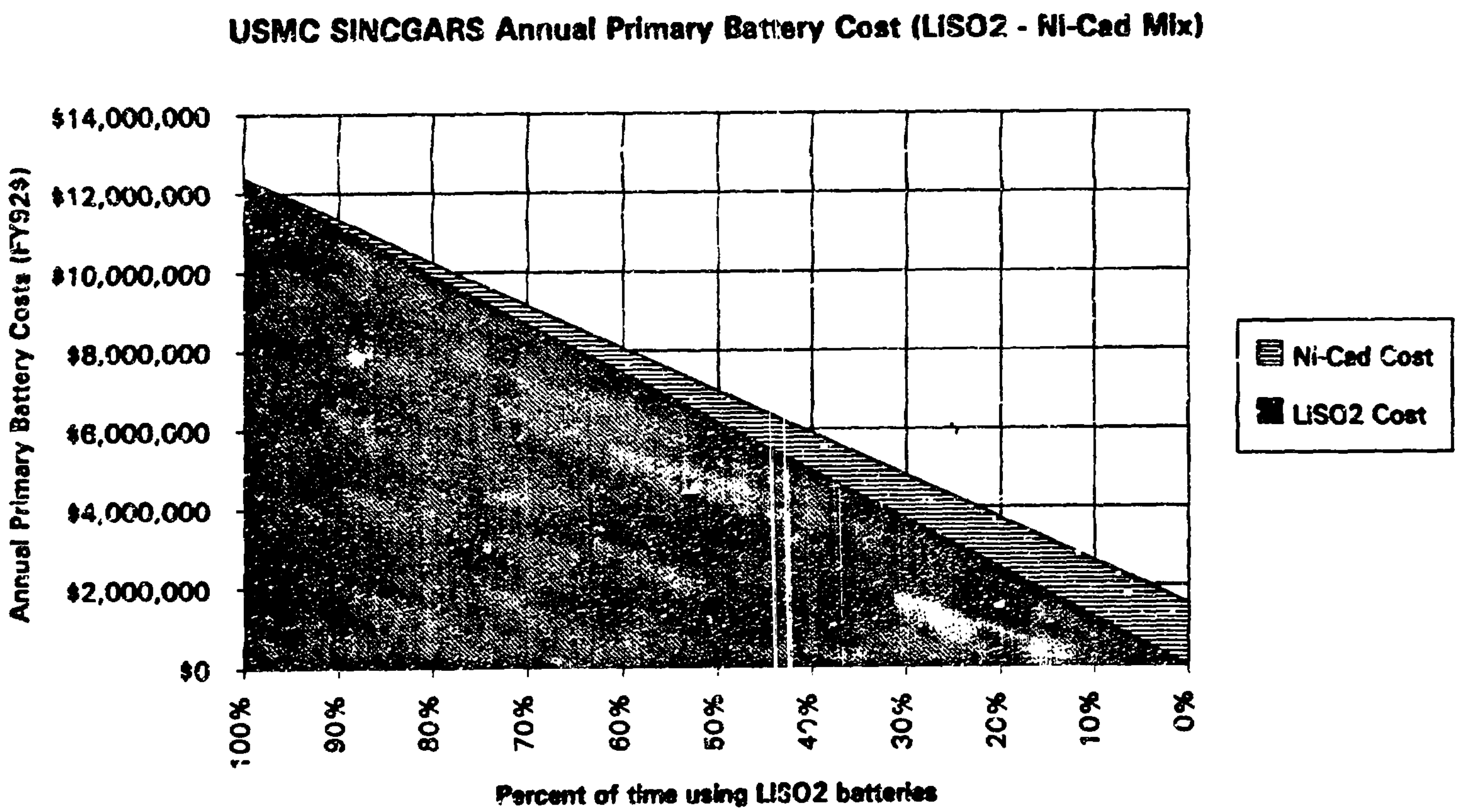

Exhibit V-1. USMC SINCGARS ANNUAL PRIMARY BATTERY COST (LiSO2-NiCAD MIX)

Pct. LiSO2	LiSO2 Cost	Ni-Cad Cost	Total
100%	$12,397,011	$0	$12,397,011
90%	$11,157,310	$156,994	$11,314,305
80%	$9,917,609	$313,989	$10,231,598
70%	$8,677,908	$470,983	$9,148,892
60%	$7,438,207	$627,978	$8,066,185
50%	$6,198,506	$784,972	$6,983,478
40%	$4,958,805	$941,967	$5,900,772
30%	$3,719,103	$1,098,961	$4,818,065
20%	$2,479,402	$1,255,956	$3,735,358
10%	$1,239,701	$1,412,950	$2,652,652
0%	$0	$1,569,945	$1,569,945

Exhibit V-1. USMC SINCGARS ANNUAL PRIMARY BATTERY COST (LiSO2-NiCAD MIX) (CONT'D)

potential for transportation weight savings if rechargeable batteries proved to be acceptable in certain operational situations.

B. LiSO2/LEAD-ACID MIX

Exhibit V-2 quantifies the total annual USMC SINCGARS primary battery and primary battery-related costs arising from a mix of LiSO2 and lead-acid batteries. The mix ranges from 100% reliance on LiSO2 batteries to 0% reliance on LiSO2 batteries (i.e., 100% reliance on lead-acid batteries). For example, if the USMC relied on LiSO2 batteries to meet 50% of the annual operational hour requirement, then the remaining 50% of the demand would be met with rechargeable lead-acid batteries. In this case, the annual LiSO2 cost would be approximately $6.2 million and the annual lead-acid cost would be an additional $0.7 million for a total cost of approximately $6.9 million, or a savings of approximately $5.5 million per year relative to 100% use of LiSO2 batteries.

The benefits that could accrue to the USMC by using a mix of LiSO2 and lead-acid batteries extends beyond potential cost savings. The primary additional benefit is the disposal issue. With a mix of batteries, the USMC would be in an excellent position to respond to changing EPA regulations or changing price or acceptance policies at BDT. Since lead-acid batteries are easily recyclable, a range of potential disposal contractors would be available, which is not the case with either LiSO2 or Ni-Cad batteries.

Other potential benefits include a reduced overall battery demand on the USMC supply system and the potential for transportation weight savings if rechargeable batteries proved to be acceptable in certain operational situations. A significant relevant fact is that there are a broad range of constant-voltage power sources that could recharge lead-acid batteries (e.g., solar powered chargers, zinc-air powered chargers), providing additional flexibility.

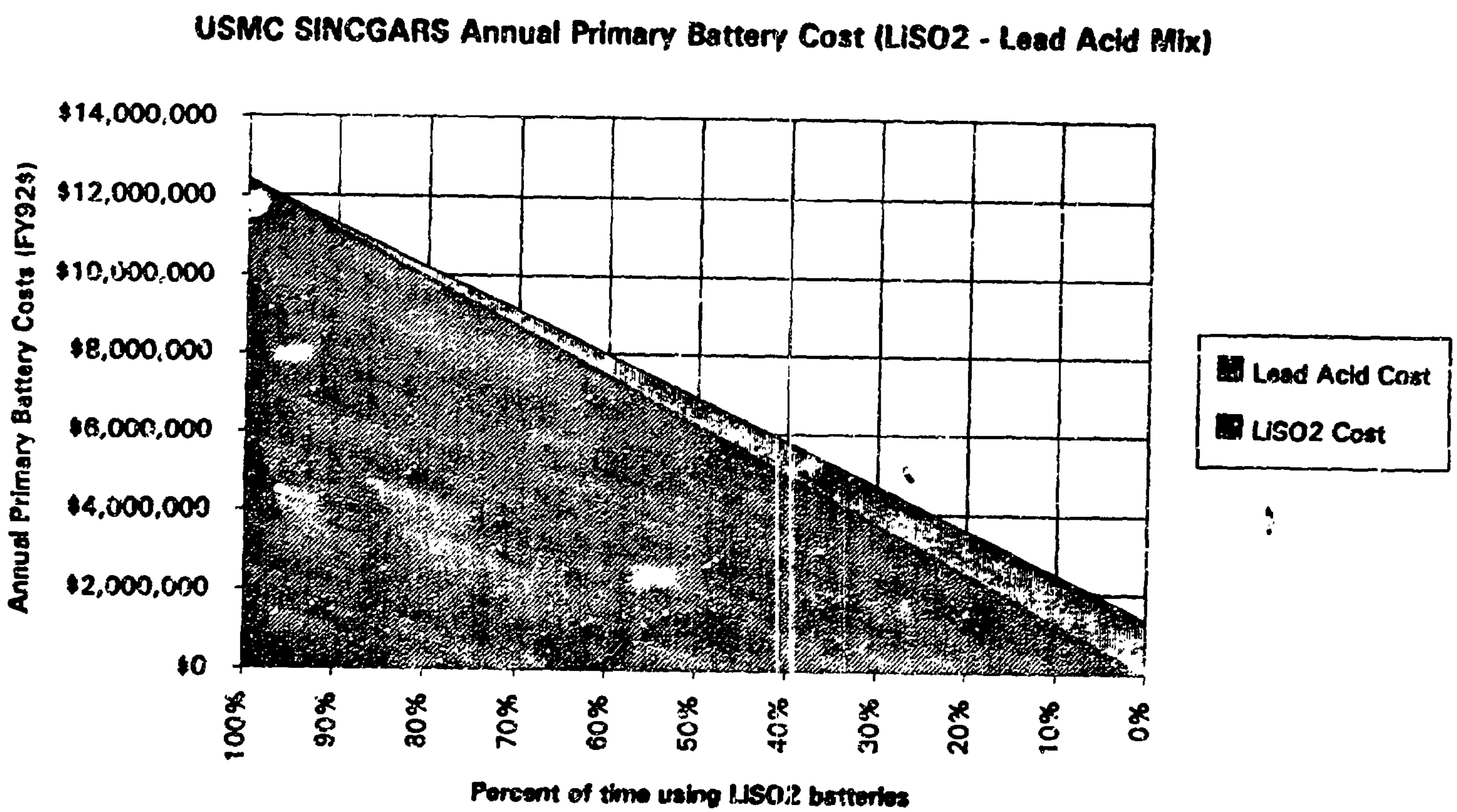

Exhibit V-2. USMC SINCGARS ANNUAL PRIMARY BATTERY COST (LiSO2 - LEAD ACID MIX)

Pct. LiSO2	LiSO2 Cost	Lead Acid Cost	Total
100%	$12,397,011	$0	$12,397,011
90%	$11,157,310	$137,895	$11,295,206
80%	$9,917,609	$275,791	$10,193,400
70%	$8,677,908	$413,686	$9,091,594
60%	$7,438,207	$551,582	$7,989,788
50%	$6,198,506	$689,477	$6,887,983
40%	$4,958,805	$827,372	$5,786,177
30%	$3,719,103	$965,268	$4,684,371
20%	$2,479,402	$1,103,163	$3,582,565
10%	$1,239,701	$1,241,058	$2,480,760
0%	$0	$1,378,954	$1,378,954

Exhibit V-2. USMC SINCGARS ANNUAL PRIMARY BATTERY COST (LiSO2 - LEAD ACID MIX)

VI. SUMMARY

The basic findings of this report are as follows:

- Two types of commercially available rechargeable batteries exist that are suitable for use with SINCGARS radios:

  - Ni-Cad, and
  - sealed lead-acid.

- Either rechargeable battery chemistry is significantly less costly on an average hourly cost basis than LiSO2.

- One LiSO2 battery provides approximately 5 times as much energy as one rechargeable battery cycle.

- All three battery chemistries are classified as hazardous waste and their disposal is regulated by the EPA (and potentially state authorities as well).

Of the two rechargeable battery chemistries analyzed in detail, lead-acid batteries are slightly preferable to Ni-Cad batteries with regard to USMC SINCGARS. The primary reasons for this conclusion are as follows:

- lead-acid batteries are less expensive than Ni-Cad batteries on a life cycle cost basis.

- lead-acid batteries are simpler and more rugged than Ni-Cad batteries.

- lead-acid batteries exhibit slightly better discharge characteristics than Ni-Cad batteries.

- The constant-voltage rechargers used for lead-acid batteries are less expensive and offer broader design choices than the constant-current rechargers required by Ni-Cad batteries.

- lead-acid batteries are easier to recycle.

- A range of lead-acid battery recyclers is available, where as there is only one EPA-licensed U.S. Ni-Cad battery recycler.

A final point is that rechargeble battery technology is advancing rapidly. Ni-Cad and lead-acid batteries are constantly improving with regard to cycle life, float life, and, to a

lesser extent, energy density. Alternative rechargeable chemistries such as NiMH may become commercialy available and cost-effective in the near future. NiMH batteries may exhibit significantly better performance than either Ni-Cad or lead-acid batteries with regard to energy density without the disposal problems associated with either Ni-Cad or LiSO2 batteries.

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APPENDIX A

EXTRACT FROM SOLID WASTE DISPOSAL ACT

EPA/530-SW-85-022

99th Congress
1st Session

COMMITTEE PRINT

S. PRT.
99-215

THE SOLID WASTE DISPOSAL ACT

AS AMENDED BY

THE HAZARDOUS AND SOLID WASTE AMENDMENTS OF 1984 (PUBLIC LAW 98–616); THE SAFE DRINKING WATER ACT AMENDMENTS OF 1986 (PUBLIC LAW 99–339); AND THE SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT OF 1986 (PUBLIC LAW 99–499)

Printed for the use of the
Senate Committee on Environment and Public Works

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leaching potential of wastes which pose a threat to human health and the environment when mismanaged.

(h) ADDITIONAL CHARACTERISTICS.—Not later than two years after the date of enactment of the Hazardous and Solid Waste Amendments of 1984, the Administrator shall promulgate regulations under this section identifying additional characteristics of hazardous waste, including measures or indicators of toxicity.

(i) CLARIFICATION OF HOUSEHOLD WASTE EXCLUSION.—A resource recovery facility recovering energy from the mass burning of municipal solid waste shall not be deemed to be treating, storing, disposing of, or otherwise managing hazardous waste for the purposes of regulation under this subtitle, if—

(1) such facility—

(A) receives and burns only—

(i) household waste (from single, and multiple dwellings, hotels, motels, and other residential sources) and

(ii) solid waste from commercial or industrial sources that does not contain hazardous waste identified or listed under this section, and

(B) does not accept hazardous wastes identified or listed under this section, and

(2) the owner or operator of such facility has established contractual requirements or other appropriate notification or inspection procedures to assure that hazardous wastes are not received at or burned in such facility.

STANDARDS APPLICABLE TO GENERATORS OF HAZARDOUS WASTE

SEC. 3002. (a) IN GENERAL.—Not later than eighteen months after the date of the enactment of this section, and after notice and opportunity for public hearings and after consultation with appropriate Federal and State agencies, the Administrator shall promulgate regulations establishing such standards applicable to generators of hazardous waste identified or listed under this subtitle, as may be necessary to protect human health and the environment. Such standards shall establish requirements respecting—

(1) recordkeeping practices that accurately identify the quantities of such hazardous waste generated, the constituents thereof which are significant in quantity or in potential harm to human health or the environment, and the disposition of such waste;

(2) labeling practices for any containers used for the storage, transport, or disposal of such hazardous waste such as will identify accurately such waste;

(3) use of appropriate containers for such hazardous waste;

(4) furnishing of information on the general chemical composition of such hazardous waste to persons transporting, treating, storing, or disposing of such wastes;

(5) use of a manifest system and any other reasonable means necesary to assure that all such hazardous waste generated is designated for treatment, storage, or disposal in and arrives at, treatment, storage, or disposal facilities (other than facilities on the premises where the waste is generated) for which a permit has been issued as provided in this subtitle, or pursuant

to title I of the Marine Protection, Research, and Sanctuaries Act (86 Stat. 1052), and

[(6) submission of reports to the Administrator (or the State agency in any case in which such agency carries out an authorized permit program pursuant to this subtitle) at such times as the Administrator (or the State agency if appropriate) deems necessary, setting out—

[(A) the quantities of hazardous waste identified or listed under this subtitle that he has generated during a particular time period; and

[(B) the disposition of all hazardous waste reported under subparagraph (A).]

(6) submission of reports to the Administrator (or the State agency in any case in which such agency carries out a permit program pursuant to this subtitle) at least once every two years, setting out—

(A) the quantities and nature of hazardous waste identified or listed under this subtitle that he has generated during the year;

(B) the disposition of all hazardous waste reported under subparagraph (A);

(C) the efforts undertaken during the year to reduce the volume and toxicity of waste generated; and

(D) the changes in volume and toxicity of waste actually achieved during the year in question in comparison with previous years, to the extent such information is available for years prior to enactment of the Hazardous and Solid Waste Amendments of 1984.

(b) Waste Minimization.—Effective September 1, 1985, the manifest required by subsection (a)(5) shall contain a certification by the generator that—

(1) the generator of the hazardous waste has a program in place to reduce the volume or quantity and toxicity of such waste to the degree determined by the generator to be economically practicable; and

(2) the proposed method of treatment, storage, or disposal is that practicable method currently available to the generator which minimizes the present and future threat to human health and the environment.

STANDARDS APPLICABLE TO TRANSPORTERS OF HAZARDOUS WASTE

Sec. 3003. (a) Standards.—Not later than eighteen months after the date of enactment of this section, and after opportunity for public hearings, the Administrator, after consultation with the Secretary of Transportation and the States, shall promulgate regulations establishing such standards, applicable to transporters of hazardous waste identified or listed under this subtitle, as may be necessary to protect human health and the environment. Such standards shall include but need not be limited to requirements respecting—

(1) recordkeeping concerning such hazardous waste transported, and their source and delivery points;

(2) transportation of such waste only if properly labeled;

(3) compliance with the manifest system referred to in section 3002(5); and

(4) transportation of all such hazardous waste only to the hazardous waste treatment, storage, or disposal facilities which the shipper designates on the manifest form to be a facility holding a permit issued under this subtitle, or pursuant to title I of the Marine Protection, Research, and Sanctuaries Act (86 Stat. 1052).

(b) COORDINATION WITH REGULATIONS OF SECRETARY OF TRANSPORTATION.—In case of any hazardous waste identified or listed under this subtitle which is subject to the Hazardous Materials Transportation Act (88 Stat. 2156; 49 U.S.C. 1801 and following), the regulations promulgated by the Administrator under this section shall be consistent with the requirements of such Act and the regulations thereunder. The Administrator is authorized to make recommendations to the Secretary of Transportation respecting the regulations of such hazardous waste under the Hazardous Materials Transportation Act and for addition of materials to be covered by such Act.

(c) FUEL FROM HAZARDOUS WASTE.—Not later than two years after the date of enactment of the Hazardous and Solid Waste Amendments of 1984, and after opportunity for public hearing, the Administrator shall promulgate regulations establishing standards, applicable to transporters of fuel produced (1) from any hazardous waste identified or listed under section 3001, or (2) from any hazardous waste identified or listed under section 3001 and any other material, as may be necessary to protect human health and the environment. Such standards may include any of the requirements set forth in paragraphs (1) through (4) of subsection (a) as may be appropriate.

STANDARDS APPLICABLE TO OWNERS AND OPERATORS OF HAZARDOUS WASTE TREATMENT, STORAGE, AND DISPOSAL FACILITIES

SEC. 3004. *(a) IN GENERAL.*—Not later than eighteen months after the date of enactment of this section, and after opportunity for public hearings and after consultation with appropriate Federal and State agencies, the Administrator shall promulgate regulations establishing such performance standards, applicable to owners and operators of facilities for the treatment, storage, or disposal of hazardous waste identified or listed under this subtitle, as may be necessary to protect human health and the environment. In establishing such standards the Administrator shall, where appropriate, distinguish in such standards between requirements appropriate for new facilities and for facilities in existence on the date of promulgation of such regulations. Such standards shall include, but need not be limited to, requirements respecting—

(1) maintaining records of all hazardous wastes identified or listed under this title which is treated, stored or disposed of, as the case may be, and the manner in which such wastes were treated, stored, or disposed of;

(2) satisfactory reporting, monitoring, and inspection and compliance with the manifest system referred to in section 3002(5);

(3) treatment, storage, or disposal of all such waste received by the facility pursuant to such operating methods, techniques, and practices as may be satisfactory to the Administrator;

(4) the location, design, and construction of such hazardous waste treatment, disposal, or storage facilities;

(5) contingency plans for effective action to minimize unanticipated damage from any treatment, storage, or disposal of any such hazardous waste;

(6) the maintenance of operation of such facilities and requiring such additional qualifications as to ownership, continuity of operation, training for personnel, and financial responsibility *(including financial reponsibility for corrective action)* as may be necessary or desirable; and

(7) compliance with the requirements of section 3005 respecting permits for treatment, storage, or disposal.

No private entity shall be precluded by reason of criteria established under paragraph (6) from the ownership or operation of facilities providing hazardous waste treatment, storage, or disposal services where such entity can provide assurances of financial responsibility and continuity of operation consistent with the degree and duration of risks associated with the treatment, storage, or disposal of specified hazardous waste.

(b) Salt Dome Formations, Salt Bed Formations, Underground Mines and Caves.—(1) Effective on the date of the enactment of the Hazardous and Solid Waste Amendments of 1984, the placement of any noncontainerized or bulk liquid hazardous waste in any salt dome formation, salt bed formation, underground mine, or cave is prohibited until such time as—

(A) the Administrator has determined, after notice and opportunity for hearings on the record in the affected areas, that such placement is protective of human health and the environment;

(B) the Administrator has promulgated performance and permitting standards for such facilities under this subtitle, and;

(C) a permit has been issued under section 3005(c) for the facility concerned.

(2) Effective on the date of enactment of the Hazardous and Solid Waste Amendments of 1984, the placement of any hazardous waste other than a hazardous waste referred to in paragraph (1) in a salt dome formation, salt bed formation, underground mine, or cave is prohibited until such time as a permit has been issued under section 3005(c) for the facility concerned.

(3) No determination made by the Administrator under subsection (d), (e), or (g) of this section regarding any hazardous waste to which such subsection (d), (e), or (g) applies shall affect the prohibition contained in paragraph (1) or (2) of this subsection.

(4) Nothing in this subsection shall apply to the Department of Energy Waste Isolation Pilot Project in New Mexico.

(c) Liquids in Landfills.—(1) Effective 6 months after the date of the enactment of the Hazardous and Solid Waste Amendments of 1984, the placement of bulk or noncontainerized liquid hazardous waste or free liquids contained in hazardous waste (whether or not absorbents have been added) in any landfill is prohibited. Prior to such date the requirements (as in effect on April 30, 1983) promul-

gated under this section by the Administrator regarding and liquid hazardous waste shall remain in force and effect to the extent such requirements are applicable to the placement of bulk or noncontainerized liquid hazardous waste, or free liquids contained in hazardous waste, in landfills.

(2) Not later than fifteen months after the date of the enactment of the Hazardous and Solid Waste Amendments of 1984, the Administrator shall promulgate final regulations which—

(A) minimize the disposal of containerized liquid hazardous waste in landfills, and

(B) minimize the presence of free liquids in containerized hazardous waste to be disposed of in landfills.

Such regulations shall also prohibit the disposal in landfills of liquids that have been absorbed in materials that biodegrade or that release liquids when compressed as might occur during routine landfill operations. Prior to the date on which such final regulations take effect, the requirements (as in effect on April 30, 1983) promulgated under this section by the Administrator shall remain in force and effect to the extent such requirements are applicable to the disposal of containerized liquid hazardous waste, or free liquids contained in hazardous waste in landfills.

(3) Effective twelve months after the date of the enactment of the Hazardous and Solid Waste Amendments of 1984, the placement of any liquid which is not a hazardous waste in a landfill for which a permit is required under section 3005(c) or which is operating pursuant to interim status granted under section 3005(e) is prohibited unless the owner or operator of such landfill demonstrates to the Administrator, or the Administrator determines, that—

(A) the only reasonably available alternative to the placement in such landfill is placement in a landfill or unlined surface impoundment, whether or not permitted under section 3005(c) or operating pursuant to interim status under section 3005(e), which contains, or may reasonably be anticipated to contain, hazardous waste; and

(B) placement in such owner or operator's landfill will not present a risk of contamination of any underground source of drinking water.

As used in subparagraph (B), the term "underground source of drinking water" has the same meaning as provided in regulations under the Safe Drinking Water Act (title XIV of the Public Health Service Act).

(4) No determination made by the Administrator under subsection (d), (e), or (g) of this section regarding any hazardous waste to which such subsection (d), (e), or (g) applies shall affect the prohibition contained in paragraph (1) of this subsection.

(d) PROHIBITIONS ON LAND DISPOSAL OF SPECIFIED WASTES.—(1) Effective 32 months after the enactment of the Hazardous and Solid Waste Amendments of 1984 (except as provided in subsection (f) with respect to underground injection into deep injection wells), the land disposal of the hazardous wastes referred to in paragraph (2) is prohibited unless the Administrator determines the prohibition on one or more methods of land disposal of such waste is not required in order to protect human health and the environment for as long as the waste remains hazardous, taking into account—

(A) the long-term uncertainties associated with land disposal,

(B) the goal of managing hazardous waste in an appropriate manner in the first instance, and

(C) the persistence, toxicity, mobility, and propensity to bioaccumulate of such hazardous wastes and their hazardous constituents.

For the purposes of this paragraph, a method of land disposal may not be determined to be protective of human health and the environment for a hazardous waste referred to in paragraph (2) (other than a hazardous waste which has complied with the pretreatment regulations promulgated under subsection (m)), unless, upon application by an interested person, it has been demonstrated to the Administrator, to a reasonable degree of certainty, that there will be no migration of hazardous constituents from the disposal unit or injection zone for as long as the wastes remain hazardous.

(2) Paragraph (1) applies to the following hazardous wastes listed or identified under section 3001:

(A) Liquid hazardous wastes, including free liquids associated with any solid or sludge, containing free cyanides at concentrations greater than or equal to 1,000 mg/l.

(B) Liquid hazardous wastes, including free liquids associated with any solid or sludge, containing the following metals (or elements) or compounds of these metals (or elements) at concentrations greater than or equal to those specified below:

(i) arsenic and/or compounds (as As) 500 mg/l;

(ii) cadmium and/or compounds (as (Cd) 100 mg/l;

(iii) chromium (VI and/or compounds (as Cr VI)) 500 mg/l;

(iv) lead and/or compounds (as Pb) 500 mg/l;

(v) mercury and/or compounds (as Hg) 20 mg/l;

(vi) nickel and/or compounds (as Ni) 134 mg/l;

(vii) selenium and/or compounds (as Se) 100 mg/l; and

(viii) thallium and/or compounds (as Th) 130 mg/l.

(C) Liquid hazardous waste having a pH less than or equal to two (2.0).

(D) Liquid hazardous wastes containing polychlorinated biphenyls at concentrations greater than or equal to 50 ppm.

(E) Hazardous wastes containing halogenated organic compounds in total concentration greater than or equal to 1,000 mg/kg.

When necessary to protect human health and the environment, the Administrator shall substitute more stringent concentration levels than the levels specified in subparagraphs (A) through (E).

(3) During the period ending forty-eight months after the date of the enactment of the Hazardous and Solid Waste Amendments of 1984, this subsection shall not apply to any disposal of contaminated soil or debris resulting from a response action taken under section 104 or 106 of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 or a corrective action required under this subtitle.

(e) SOLVENTS AND DIOXINS.—(1) Effective twenty-four months after the date of enactment of the Hazardous and Solid Waste Amendments of 1984 (except as provided in subsection (f) with respect to underground injection into deep injection wells), the land disposal

APPF' DIX B

EPA LETTER TO DLA RE: DISPOSAL OF LISO2 BATTERIES

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE
WASHINGTON, D.C. 20460

Mr. Dick Bruner
Executive Director
Technical and Logistics Services (DLA-S)
Defense Logistics Agency
Cameron Station
Alexandria, Virginia 22314

Dear Mr. Bruner:

This letter is in response to a number of requests made by the Department of Defense (DOD) for guidance from the Environmental Protection Agency (EPA) on the regulatory status of spent and/or discarded lithium-sulfur dioxide (Li/SO_2) batteries.

EPA recognizes that the Department of Defense has done extensive work in assessing the hazards posed by lithium batteries1/ and in developing procedures for managing spent or discarded Li/SO_2 cells. In fact, DOD currently considers these batteries to be hazardous wastes for management purposes. Consequently, the purpose of this letter is simply to render an Agency opinion as to whether lithium batteries are hazardous wastes under the rules promulgated pursuant to the Resource Conservation and Recovery Act of 1976 (RCRA), and to clarify the application of those rules to the management (i.e., disposal) of lithium batteries.

Based on a careful review of the available data and information, EPA has concluded that lithium-sulfur dioxide batteries clearly exhibit the characteristic of reactivity as defined in 40 CFR 261.23. Handlers of these wastes must, therefore, comply with all applicable standards under 40 CFR Parts 262 to 266, and 124, 270, and 271. Under these standards, the land disposal of reactive waste is prohibited unless the waste is treated or otherwise rendered non-reactive. (See 264.312 and 265.312).

Under 40 CFR 261.23, a solid waste is considered to be reactive if a representative sample of the waste has <u>any</u> of the following properties:

(1) It is normally unstable and readily undergoes violent change without detonating

(2) It reacts violently with water.

(3) It forms potentially explosive mixtures with water.

(4) When mixed with water, it generates toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment.

1/ The term 'lithium batteries' as used in this letter applies only to those batteries or cells commonly referred to as lithium-sulfur dioxide batteries. At this time, EPA does not have sufficient information to make a blanket determination as to whether lithium batteries using other cathode materials (i.e., thionyl chloride ($SOCl_2$), polycarbon monofluoride ($(CF)_x$), manganese dioxide (MnO_2), iodine (I), silver oxide (Ag_2O), silver chromate (Ag_2CrO_4), vanadium pentoxide (V_2O_5), iron sulfide (FeS), copper oxide (CuO), and lead bismuthate ($Bi_2Pb_2O_5$)) exhibit the characteristic of reactivity. Consequently, handlers of these lithium batteries must evaluate them against the reactivity characteristic identified in 261.23 as well as the other hazardous waste characteristics to determine if the batteries should be handled as hazardous wastes.

(5) It is a cyanide or sulfide bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment.

(6) It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement.

(7) It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.

(8) It is a forbidden explosive as defined in 49 CFR 173.53 or a Class B explosive as defined in 49 CFR 173.88.

The lithium in Li/SO_2 cells will form potentially explosive hydrogen gas when mixed with water (261.23(a)(3)), and Li/SO_2 cells are capable of violent rupture or reaction if subjected to a strong initiating source or if heated under confinement (261.23(a)(6)). However, of primary concern is the potential, under existing management practices, for components of the batteries to generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment when those components are mixed with water or exposed to certain pH conditions (261.23(a)(4) and (a)(5)).

A review of the existing literature clearly indicated that Li/SO_2 batteries are capable of violent reaction if mishandled by being exposed to a strong initiating source or heated under confinement. Incidents of violent cell ruptures, particularly laboratory abuse tests and under actual field conditions. Although newer designs of Li/SO_2 batteries incorporate a number of safety features that reduce their explosive potential in most circumstances, forced discharge below zero volts, penetration, or heating in a confined area may still cause vented batteries to violently rupture.

Lithium-sulfur dioxide batteries typically contain strips of lithium metal as the anode as well as a non-aqueous electrolyte consisting primarily of sulfur dioxide (SO_2) and smaller concentrations of acetonitrile (CH_3CN) and a lithium salt, typically lithium bromide (LiBr). Lithium is known to react with water to produce potentially explosive hydrogen gas. Although lithium battery cells are constructed such that their reactive components do not ordinarily come into contact with water under normal operating conditions, if placed in a landfill, or otherwise improperly managed, these batteries will eventually corrode and allow their reactive constituents to come into contact with water. The reactive nature of lithium is of particular concern since substantial quantities of partially discharged cells or cells of the unbalanced, or excess lithium type, are often disposed of together. The Agency believes that under existing management practices, (i.e., storage in drums or disposal of batteries in drums), potentially explosive concentrations of hydrogen gas might reasonably by expected to occur (261.23(a)(2)).

The Agency also believes that the practice of accumulating large quantities of Li/SO_2 batteries could result in concentrations of toxic gases, vapors, or fumes in sufficient concentrations present a danger to human health or the environment. As mentioned previously, newer lithium battery cells are designed to automatically vent SO_2 and other components to the air to minimize the possibility of explosion due to pressure when the cells are exposed to external heat or short circuiting. During operations such as collection, processing, and disposal, the batteries may be exposed to mechanical shock, short circuiting, immersion in water or penetration. These operations are likely to cause cells to rupture and/or vent their reactive materials in potentially dangerous concentration if venting or rupture occurs in a confined area or if significant numbers of cells are involved. Sulfur dioxide is a strong irritant and is capable of causing incapacitation at concentrations above 50 ppm and has proven to be life-threatening at concentrations of 400-500 ppm. In addition, acetonitrile (CH_3CN) will decompose to form toxic cyanide fumes when heated. Lithium also reacts with acetonitrile to produce lithium cyanide (LiCN), which in turn can react with weak acids to produce toxic hydrocyanic gas. Potentially dangerous concentrations of these, as well as other toxic fumes and vapors, may, therefore, be expected to result if the reactive components of these batteries are exposed to water or acidic conditions during collection, processing or disposal operations.

The inherently reactive nature of lithium-sulfur dioxide batteries was, in fact, demonstrated by a fire at the Groton Point Landfill in Groton, Connecticut on April 20, 1981. In that incident, a number of drums of lithium sulfur dioxide batteries, which were improperly handled, caught fire due either to short circuiting or contact with moisture. The fire resulted in a number of violent ruptures as well as the generation of toxic gases and fumes which posed a hazard to personnel combating the fire.

The Agency recognizes that the degree of hazard posed by lithium battery cells depends upon a large number of variables including:

* the quantity of cells accumulated in one location and the condition of the cells (e.g., whether they have vented, are partially depleted, fully discharged, of the balanced or unbalanced type, etc.)

* the procedures used in storing, transporting, disposing, or otherwise handling spent or discarded batteries.

* the proximity of workers or the general public to the batteries.

Due to the variable nature of the hazards posed by lithium batteries under different conditions, the Agency had considered whether it was feasible to establish accumulation levels below which quantities of lithium batteries would not be considered reactive and, therefore, not subject to the hazardous waste regulations. However, the Agency does not believe that there is sufficient information available at this time to reasonably establish such exemption levels specifically for lithium batteries.

The Agency's conclusion that lithium-sulfur dioxide batteries exhibit the characteristic of reactivity does not affect the applicability of other provisions of the hazardous waste regulations. Of specific interest to DOD may be 261.5, which conditionally exempts from hazardous waste regulation all hazardous wastes from generators that do not generate more than 1000 kg. per month of hazardous waste or accumulate more than 1000 kg. of such waste at any time.2/ However, you should be aware that when calculating the quantity of waste generated for purposes of assessing small quantity generator status, all hazardous wastes from all sources that are generated at a particular site3/ in a one-month period or which are accumulated over any period of time must be counted. You should also be aware that Congress is currently considering amendments to RCRA that would lower the small quantity generator exemption level to 100 kg.

As mentioned previously, the practical effect of the Agency's conclusion that lithium batteries are reactive wastes is that regulated quantities of these batteries may not be disposed of at most hazardous waste land disposal facilities. Sections 264.312 and 265.312 prohibit landfilling of reactive wastes unless they are treated, rendered, or mixed such that they no longer exhibit the characteristic of reactivity and unless the general requirements for reactive wastes contained in 264.17(b) have been met.

If you have any questions about the information contained in this letter, please do not hesitate to contact either Francine Jacoff or Robert Axelrad, of my staff at (202) 382-4761.

Sincerely yours,

Lee M. Thomas
Assistant Administrator

2/ Acute hazardous' wastes are subject to a 1 kg. exemption level for quantities generated in a one-month period or accumulated over any period of time. As a characteristic hazardous waste, lithium batteries are subject to the 1000 kg. exemption level

3/ See 260.10 definitions for 'individual generation site' and 'on-site'.

Regulations:

The transportation of lithium cells, batteries, and devices containing those power sources around the USA, is governed by US Department of Transportation (DOT) regulations. These regulations are found in title 49 of the Code of Federal Regulations (CFR). Lithium cells have been determined as hazardous materials for transportation and regulations covering their movement may be found in the CFR and in various exemptions issued by DOT. Briefly, fresh cells fall into three classes. Cells containing less than 0.5 grams of lithium metal or batteries comprised of one or more such cells with an aggregate quantity of not more than one gram of lithium metal are exempt from the regulations providing that certain requirements are met. Cells with more than 0.5 grams but less than 12 grams of lithium metal of batteries comprised of such cells are covered by specific exemptions.

Up until 5 December 1982, cells with no further use, that met the requirements of DOT-E 7052, could be transported to a disposal site under DOT-E 8441. Now this exemption has been incorporated into the CFR. The regulation states:

(a) Lithium batteries, for disposal, comprised of one or more cells may be offered for transportation to a permitted storage facility and disposal site by motor vehicle only, if the battery:

(1) when new, contained not more than 12 grams of lithium metal per cell;

(2) is equipped with an effective means of preventing external short circuits.

(3) is classified and offered for transportation as an ORM-C; and

(4) is overpacked in a strong fiberboard box, or metal or fiber drum which complies with paragraph 173.24.

(b) Paragraph (a) does not apply to lithium batteries,which, when new, were excepted from regulation under paragraph 173.206(f).

Paragraph (b) relates to the 0.5 gram rule

Packaging:

Cells and batteries have to be packaged to prevent the possibilities of external short circuit. In BDT's experience, most people have accomplished this by wrapping individual cells in a plastic bag. However, cells have been received in which the individual terminals have been taped with adhesive insulating tape and in some instances the original packaging has been well designed and its re-use has been possible without any other precaution. All of these options are acceptable to BDT.

Outer packaging used to date has been either a DOT specification 12B fiberboard box with a gross weight not to exceed 65 pounds or metal drums with removable heads and of DOT specification 17H or 17C with a gas tight gasket. When metal drums are used, the inner containers or batteries must be separated from each other and all inner surfaces by at least one inch thickness of vermiculite or other equivalent non-combustible material. The regulations allows DOT specification 21C fiber drums to be used.

Handling:

To obtain the very latest data on the safe handling of cells and batteries that you are using and of depleted systems that are being prepared for disposal you should contact your vendor(s).

However, your operators should be instructed in the areas of how to avoid short circuits and what to do if they encounter cells that are warm to the touch, are swollen, or have leaked electrolyte. It is wise to avoid sudden shocks to the cells and batteries.

Marking and Labelling:

The proper shipping name: Waste lithium batteries for disposal

Generator information: See enclosed hazardous waste label

One label should be used: ORM-C

Shipping:

Regulations allow lithium batteries to go by motor vehicle only.

Special Requirements:

DOT regulations allow waste lithium batteries for disposal to be shipped by road to a disposal site using an ORM-C designation. This designation is used for those materials which have inherent characteristics that make them unsuitable for transportation, unless properly identified and prepared for shipment. Since they are regulated and going to a disposal site, they are a hazardous waste and therefore subject to regulation by the USEPA. This is not a major requirement beyond the regulation of DOT. However, if your company is a generator of hazardous waste i.e. produces more than 100 kg/month, in total of hazardous waste, it has to use a manifest as a shipping paper. A uniform New York State Hazardous Waste Manifest must be used for materials being shipped to BDT. Also, because the waste is hazardous, special permitted haulers have to be used. Such haulers are required to have the name of the disposer on their permits. BDT can provide a list of haulers that meet this requirement.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION II

PERMIT

Permittee: BDT, Inc. - Operator
Greatbatch Enterprises, Inc. - Owner
4255 Research Parkway
Clarence, New York 14031

EPA I.D. NUMBER NYD000632372
Effective Date: April 17, 1986
Expiration Date: April 17, 1996

This permit is issued by the United States Environmental Protection Agency (EPA) under authority of the Resource Conservation and Recovery Act (RCRA) Subtitle C, 42 U.S.C. 6921-6631 (1976, as amended by Supp IV 1980 and the Hazardous and Solid Waste Amendments of 1984 (HSWA)) and EPA regulations to BDT, Inc. (hereafter called the Permittee), to operate a hazardous waste management facility located at 4255 Research Parkway, Clarence, New York 14031.

The Permittee must comply with all terms and conditions of this permit. This permit consists of the conditions contained herein (including those in any attachments) and the applicable regulations contained in 40 CFR Parts 260 through 264 and 270 and 124 as specified in the permit. Applicable provisions are those which are in effect on the date of issuance of this permit (See 40 CFR 270.32(C)).

This permit is based on the assumption that the information submitted in the permit application attached to the Permittee's letter dated March 20 1983, as modified by subsequent amendments dated July 13, 1984, January 15, 1985, March 15, 1985, April 12, 1985, May 21, 1985, October 24, 1985, November 19, 1985, and January 16, 1986 (hereafter referred to as the application) is accurate and that the facility will be constructed and operated as specified in the application.

This permit is also based in part on the provisions of Sections 206, 212 and 224 of HSWA which modify Sections 3002, 3004 and 3005 of RCRA. These require corrective action for all releases of hazardous waste or constituents from any solid waste management unit at a treatment, storage, or disposal facility seeking a permit, regardless of the time at which waste was placed in such unit, and provide the authority to review and modify the permit at any time. EPA has determined that there have been no uncorrected releases of hazardous waste or hazardous constituents to the environment. This determination is based on review of information submitted by the Permittee, EPA RCRA and other environmental program permitting and enforcement files and a site inspection. Section 224 requires (after September 1, 1985) generators that treat, store, or dispose of waste on-site to certify (at least annually) that the volume or quantity and toxicity of the waste has been reduced to the maximum degree economically practicable, and that the method used to manage the waste minimizes the present and future threat to human health and the environment to the extent practicable. The permittee's failure in the application or during the permit issuance process to disclose fully all relevant facts, or the Permittee's misrepresentation of any relevant facts at any time may be grounds for the termination or modification of this permit (see 40 CFR 270.41, 270.42 and 270.43) and potential enforcement action. The Permittee must inform EPA of any deviation from or changes in any information submitted which would affect the Permittee's ability to comply with the applicable statuses, regulations or permit conditions.
The permit is effective as of April 17, 1986 and shall remain in effect until April 17, 1996 unless revoked and reissued o terminated in accordance with 40 CFR 270.41 or 270.43, or Section 212 of the HSWA, or continued in accordance with 40 CFR 270.51(a).

Issued by the EPA - Region II.

Christopher J. Daggett — Date
Regional Administrator
U.S. Environmental Protection Agency
Region II

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APPENDIX C

BDT LISO2 BATTERY PACKAGING REQUIREMENTS

PREFERRED
PROPER PACKAGING PROCEDURE
"LITHIUM BATTERIES"
APRIL 25, 1991

A. "HERMETICALLY SEALED LITHIUM CELLS"

These cells would be in excellent condition with no punctures or leaks.

OPTION 1. Package each cell in a box so that each cell is separated by cardboard. An egg carton would be of good use. Be sure each cell cannot come in contact with each other. Fill each box with vermiculite.

OPTION 2. Place each cell in its own plastic bag and then seal the bag. (Heat Seal)

OPTION 3. Tape the ends of each cell and then place them in a drum with vermiculite separating each.

* Go to Section D if the above material applies to your situation.

B. "UNSEALED LITHIUM CELLS"

These cells are in poor condition. They would have cracks, punctures, leaks and open tops. "All packaging of this type of cell should take place in a "Dry Room." The following precautions should be taken; wear gloves, a respirator, chemical resistant suit and eye protection.

OPTION 1. Place each cell in its own individual foil pouch with plastic lining/plastic bags and heat seal the pouch closed. If these types of batteries are not packaged in this manner, there may be extra costs for treatment of the packing material.

* Go to Section D if the above material applies to your situation.

C. "BATTERY COMPONENTS WITH OR WITHOUT ELECTROLYTE"

This would include component parts, (ex. tabs, screens, jellyrolls, exposed lithium, plastic, etc.) All packaging of this material should take place in a "Dry Room." The following precautions should be taken; wear gloves, a respirator, chemical resistant suit and eye protection.

OPTION 1. Place this material into a foil bag. Flush the bag out with an inert gas (argon or nitrogen), then heat seal the foil bag.

* Go to Section E if the above material applies to your situation.

D. "DRUM SELECTION, PACKING MATERIAL, LABELING"

1. A 5-35-55 gallon drum can be used. It must meet DOT requirements.

2. Vermiculite can be used to fill void space within the drum. It will also act as a "cushion" for the material during transport.

3. "Waste Lithium Batteries for Disposal" is the proper DOT description. The hazard class is ORM-C and an ORM-C mark is required on the drum.

Material that falls into any of the categories (A-C) must be segregated from each other.

If you have any further questions regarding Lithium Batteries, please contact BDT, Inc. at (716) 759-2868. Ask for Mr. Tom Dobmeier or appropriate Operations Personnel.

If these procedures are not followed, material will be subject to rejection and/or additional charges.

E. "DRUM SELECTION, PACKING MATERIAL, LABELING"

1. A 5-35-55 gallon drum can be used. It must meet DOT requirements.

2. Vermiculite can be used to fill void space within the drum. It will also act as a "cushion" for the material during transport.

3. "Waste water reactive solid, nos" is the proper DOT description. The hazard class is flammable solid. The ID number is UN2813. A flammable solid and dangerous when wet label is required.

APPENDIX D

INMETCO NI-CAD BATTERY PACKAGING REQUIREMENTS

Ni-Cd and Ni-Fe Battery Processing Conditions

1. All Ni-Cd and Ni-Fe batteries which are to be processed by Inmetco shall be delivered, freight prepaid, to Inmetco's facility at Ellwood City, Pennsylvania.

2. All connecting straps are to be severed or removed between Ni-Cd and Ni-Fe batteries prior to the delivery of such batteries to Inmetco.

3. Large Ni-Cd or Ni-Fe batteries are to be shipped to Inmetco stacked and banded on pallets. Smaller batteries may be delivered packed in cubic yard cardboard boxes or in drums.

4. Inmetco will receive: * Drained and Undrained Ni-Cd and Ni-Fe Batteries

5. Inmetco requires that the processing and drum disposal fees, relating to any shipment, be paid prior to, or upon, the delivery of such shipment to Inmetco and, in any event, prior to the unloading of the shipment at Inmetco's facility unless other arrangements have been pre-approved from our Accounting Department. Inmetco requires a three day advance notice of shipment and this material also requires an Inmetco sales order.

6. Generator/shipper shall be responsible for complying with all federal, state and local laws and regulations relating to the packing, labeling, manifesting and transportation of the Ni-Cd and Ni-Fe batteries, until such time as such batteries are accepted by Inmetco and unloaded at its Ellwood City facility.

7. Title to the Ni-Cd and Ni-Fe batteries, and responsibility for the disposal thereof, shall pass to Inmetco only at such time that the batteries have been unloaded at its Ellwood City facility and Inmetco has received the processing and drum disposal fees, as set forth above, relating to the shipment in question.

8. All batteries deemed hazardous must be shipped on a Pennsylvania hazardous waste manifest and by a Pennsylvania licensed hazardous waste hauler.

9. Failure to comply with the above requirements may result in rejection of the material and returned at shipper's expense.

10. Normal delivery is Monday through Friday, 8 a.m. - 3 p.m., unless otherwise approved in writing.

Rev. 11/19/91

*Please contact us for current pricing.